Efficacy of Herbicidal weeds control in Groundnut (Arachis hypogaea L.) at varying levels of Sulphur

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Abstract- *The prominent dicot weed species found to infest the experimental crop were Amaranthus spinosus, Amaranthus viridis, Phyllanthus niruri, Euphorbia hirta, Trianthema portulacastrum and Verbesina encelioides, whereas, Cyperus rotundus, Cynodon dactylon, Dactyactenium aegypticum and Cenchrus biflorus were the major narrow leaf weed species noted to invade the crop at later stages of growth and in comparative low intensity. The results indicated that all the weed control treatments caused significant reduction in weed density and dry matter accumulation of weeds at all stages of crop in comparison to weedy check treatment which was noted to be the most severely infested with weeds. The highest weed density of 46.58 per 0.25 m^2 was observed in weedy check plot at 35 DAS that declined to 39.13 at 70 DAS and 28.99 at harvest stage. This could be ascribed possibly to the severe competition for moisture, nutrients, space, light, shadiness and short life of weeds resulting in exterminating of some species. The weed dry matter production of 946.0 kg/ha recorded at 35 DAS under treatment increased exponentially to 2284.9 kg/ha at 70 DAS and 2729.0 kg/ha at harvest. This profound increase in density and dry matter production of weeds under weedy check treatment might be attributed to uninterrupted growth of weeds throughout the crop season coupled with greater competitive ability than crop that was almost smothered due to fast growing of weeds. After weed free, application of various herbicides viz., pendimethalin at 0.75 kg/ha (PE), imazethapyr at 100 g/ha (PE) and fluazifop-p-butyl at 0.20 kg/ha at 25 DAS also led to significant reduction in weed population and their dry matter at all the stages of crop growth in comparison to weedy check. However, these herbicides varied in their performance among themselves, too. The magnitude of weed control varied significantly between herbicides and HW at 25 DAS. Pre emergence application of pendimethalin at 0.75 kg/ha recorded mean density of 2.64, 2.42 and 2.21 per/m^2 and weed dry matter of 140.2, 324.3 and 457.2 kg/ha at 35 and 70 DAS and at harvest stages, respectively and thus emerged as the most effective treatment by controlling the weeds to the tune of 85.18, 85.81 and 83.22 per cent at these stages than weedy check. However, it was found at par with one HW at 25 DAS. Application of imazethapyr at 100 g/ha (PE) was observed to be the next superior herbicidal treatment. It represented 81.6, 78.1 and 74.3 per cent reduction in dry matter of weeds at 35, 70 DAS and harvest stages of than unweeded control, respectively.*

Keywords- BLW (Broad leaved weeds), DAS (Days after sowing), HW (Hand weeding), WAS (Weeks after sowing), AHAS (Acetohydroxy acid synthase), ALS (Acetolactate synthase), SMW (Standard meteorological week).

I. INTRODUCTION

Groundnut (Arachis hypogaea L.) is an important edible oilseed crop of India popularly known as peanut, monkeynut and locally called as ‘moongphali’. It is world’s largest source of edible oil, ranks 13th among the food crops as well as 4th most important oilseed crops of the world (Ramanathan, 2001). It is mainly grown in kharif season. It belong to family leguminoseae and sub family papilionaceae. Groundnut kernels contain high quality edible oil (48 per cent), easily digestible protein (26 per cent) and carbohydrates (20 per cent). In India, 80 per cent of the total produce is used for oil extraction,11 per cent as seed, 8 per cent as direct food and only 1 per cent produce is exported. The vegetable oil consumption in India is continuously rising and has sharply increased in the couple of years touching around 12.4 kg/capita/year. This is still lower than the world average of 17.8 kg/capita/year. The developed western world has per capita consumption of 44-48 kg/capita/year (Hedge, 2002).

Groundnut occupies premier position with regards to area and production in India. India accounts about 20% area and less than 10% production of oilseeds of the world. Whereas, groundnut accounts for 40% of the area and 30% of the production of total oilseeds grown in India (Anonymous, 2009-10).The important groundnut producing states of the country are Gujarat, Andhra Pradesh, Karnataka, Tamilnadu, Maharastra, Rajasthan, Uttar Pradesh and Punjab. Rajasthan is one of the major groundnut producing states of the country. Groundnut is the principal oilseed crop of the kharif season of this state. It was grown on 3.97 lakh hectares in the state with a total production of 4.18 lakh tones and average productivity of 1051 kg/ha (Anonymous, 2012). Lack of improved cultivation practices, cultivation on marginal and sub marginal lands of poor fertility, inadequate fertilization, heavy weed infestation, high sensitivity to pests and diseases and non availability of suitable varieties are the major constraints in groundnut cultivation. Heavy weed infestation appears to be the most serious menace in groundnut production causing extensive losses. Because of its short sature and initial slow growth in comparison to fast growing weeds, weeds smother this crop at every stage by sharing water, nutrients, space, solar radiation and other resources resulting in yield losses ranging between 15-75 per cent (Jat et al., 2011). Giri et al. (1998) reported an average yield loss of 89% due to weed infestation in irrigated summer groundnut. Dev Kumar and Giri (1998) have also reported mortality of plant in groundnut due to weed suppression. Groundnut emerges 5 to 7 days after sowing and once the weeds overtake the crop and begin to shade it, the effect becomes more serious within this period. It is the most critical period for crop to be kept free of weeds. High yielding varieties of groundnut are highly responsive to higher fertility levels and susceptible to their associated weeds. Weed management is virtually important not only to check the losses caused by them but also to increase the fertilizer use efficiency. Physical or mechanical methods are the traditional methods of weed control in groundnut which are cumbersome, time consuming and labour intensive, also. However, their additional advantages of improving aeration, making soil loose and porous and soil moisture conservation cannot be ignored. But, with increasing crisis of labour in the era of intensive cropping system, exploring the possibility of herbicidal weed control in groundnut deserves attention. High dose of herbicides may also leave residue in the soil to injure the subsequent crops and create the pollution hazard also, (Pahwa and Prakash, 1996). Weed management involving use of selective herbicide to keep the crop weed free during early stage of crop growth can be a good answer to such problem. Optimization of mineral nutrition is also a key factor to enhance productivity of groundnut. Oilseeds are energy rich crops and hence the requirement of major as well as secondary and micro nutrients is high. Sulphur is one of the plant nutrients in which most of the Indian soils are deficient. In Rajasthan, it has been reported to be deficient mainly in the soils of Jaipur, Jodhpur and Udaipur districts (Tandon, 1986). Sulphur is one of the essential plants nutrients which is best known for its role in the synthesis of sulphur containing amino acids like methionine (20% S) and cystine (27% S) and synthesis of proteins, chlorophyll and oil. Moreover, it is also associated with the synthesis of vitamins (biotine, thiamine), metabolism of carbohydrates, proteins and fats. sulphur is also known to promote nodulation in legumes thereby increasing N fixation and associated with the crops of spurious nutrition and market quality. Global reports of sulphur deficiency and consequent crop responses; particularly in oilseed crops like groundnut are quite ostensible (Singh and Bairathi, 1980). Shah and khan (1987) also observed that oilseed crops respond remarkably to sulphur and balanced fertilization. Gypsum is an effective and cheaper source of sulphur and huge deposits of it are available in Rajasthan. In view of these factors, the present investigation entitled “Efficacy of herbicidal weed control in groundnut (Arachis hypogaea L.) at varying levels of sulphur” undertaken during kharif, 2016 with the following objectives:- (i) To assess the effect of weed control methods and sulphur fertilization on growth, yield and quality of groundnut. (ii) To find out an effective and economically viable method of weed control in groundnut. (iii) To study crop-weed competition. (iv) To work out the sulphur use efficiency and optimum dose of sulphur for groundnut. Attempt has been made to cite as much literature as possible on groundnut but due to paucity of adequate experimental evidences, especially on herbicides, similar research work on other related crops of kharif oilseeds legumes mainly the soybean has also been reviewed, wherever felt necessary.

Effect of weed control:- Effect on weeds:-A green house study was conducted by Vega et al. (2000) to evaluate the efficacy of post-emergence herbicides in soybean. Glyphosate (1494 g/ha) and imazethapyr (80 g/ha) showed effective weed control resulting into weed mortality of 100 and 67 per cent, respectively. Chandel and Saxena (2001) conducted a weed control experiment in soybean on silt loam soil of Pantnagar. They recorded the lowest weed dry matter, weed density and highest weed control efficiency with HW twice done at 30 and 45 DAS treatment. It was closely followed by alachlor at 2.0 kg/ha, imazethapyr at 100 g/ha and trifluralin at 1.0 kg/ha,respectively. Results of an another a study conducted by Kumar et al. (2004) at Hisar indicated that pendimethalin at 1.5 kg/ha (PE) + HW at 30 DAS recorded the significnalty lowest density of carpet weed and purple nutsedge and dry weight of weeds in green gram. It was followed by one HW at 30 DAS and pendimethalin at 1.5 kg/ha treatments. Rathi et al. (2004) evaluated the effect of various weed management treatments in urdbean at Kanpur. They noted the lowest density of Cyperus rotundus, Parthenium hysterophorus, Trianthema monogyna and Phyllanthus niruri and dry matter of weeds with two hand weedings done at 20 and 40 DAS which was closely followed by pendimethalin at 0.5 kg/ha + HW at 30 DAS. A weed control study was carried out at Pantnagar against a wide range of weed species viz., Echinochloa colonum, Parthenium hysterophorus, Trianthema monogyna, Celosia argentea, Cyperus species and Commelina benghalensis in soybean by Singh et al. (2004). They found that application of imazethapyr at 75 g/ha at 7 DAS had a wide spectrum weed control and very high weed control efficiency in comparison to other treatments. It did not cause any phytotoxic effect on the crop, too. Halvanker et al. (2005) studied the effect of herbicides on weed dynamics and yield of soybean at pune. They found that two HW at 30 and 45 DAS was the most effective in reducing the density and dry weight of weeds and was followed by imazomox + imazethapyr at 75 g/ha, alachlor at 2.0 kg/ha and imazomox + imzethapyr at 75 g/ha treatments, respectively. Shete et al. (2007) studied the effect of cultural practices and post emergence herbicides against weed control in soybean. They reported that post emergence application of imazethapyr at 87.5 g/ha represented the lowest weed count and highest weed control efficiency and was accompanied by imazethapyr at 75 g/ha. A three years field experiment was carried out at Ismalia Agriculture Research Station, Agriculture Research Centre in Egypt by Ahmed et al. (2008) to study the effect of the selected herbicides (pendimethalin,oxyflurofen, fluazifop-p-butyl and clethodium) on weed control. Results indicated that pendimethalin as pre- emergence treatment at recommended rate (0.75kg/ha) gave the highest reduction in number and dry weight of weeds per unit area. Dhaka (2011) studied the efficacy of various weed management treatments in sesame at Jobner. He recorded the lowest weed count and dry weight of weeds in the plots treated with pre-emergence application of imazethpyr at 0.15 kg/ha + HW at 30 DAS which showed statistical equivalence with HW twice at 20 and 40 DAS treatment. A weed control experiment in groundnut was conducted by Bhale et al. (2012) at Akola in Maharastra during 2009-10. They recorded that two hand weedings at 15 and 30 DAS were effective in reducing weed count and weed biomass, increasing WCE and thereby increasing developed pods and pod yield in groundnut.

Growth attributes:- A weed control experiment was conducted by Chandel and Saxena (2001) at pantnagar on soybean. They recorded the maximum plant height and dry matter accumulation with two hand weedings done at 30 and 45 DAS. It was followed by application of fenoxyprop-p-ethyl at 50 g, trifluralin at 1.0 kg, imazethapyr at 75 and 100 g and alachlor at 2.0 kg/ha, respectively. The maximum number of trifoliates/plant were noted with the application of imazethapyr at 75 g/ha. Mishra et al. (2004) evaluated the bioefficacy of herbicides against Cuscuta in blackgram and found that application of pendimethalin at 1.0 kg/ha as pre plant incorporation or pre-emergence recorded the highest leaf area and dry matter /plant. It was accompanied by imazethapyr at 0.5 kg/ha in enhancing these characters. Raman and Krishanmoorthy (2005) reported that two hand weedings at 20 and 40 DAS recorded the highest number and weight of nodules/plant and dry matter production in greengram among all the treatments, evaluated. However, it was found at par with pendimethalin at 1.0 kg/ha + HW at 20 DAS and fluchloralin at 1.0 kg/ha + HW at 20 DAS treatments. Application of pendimethalin and fluchloralin alone, each at 1.0 kg/ha also significantly enhanced these parameters over weedy check but found inferior to above treatments. Kushwah and Vyas (2006) studied the bio-efficasy of different herbicides in soybean at Sehore and found that post emergence application of imazethapyr at 0.075 kg/ha significantly increased the dry matter accumulation, plant height and number of branches/plant in comparison to weedy check and quizalfop-ethyl at 38 and 50 g/ha treatments. Freitas et al. (2008) conducted an experiment in Rio De Janeiro, Brazil to compare various weed management methods under soybean no tillage cultivated over pearl millet straw (managed with cutting roller or glyphosate). They reported that higher weed control efficacy was observed with application of post emergence herbicides, fluazifop- p- butyl + fomesafen (0, 100+125 and 300+250 g/ha) than cutting roller, resulting in high yields. A field experiment was conducted by Bhalerao et al. (2011) at Ahmednagar in Maharastra. They reported that growth of groundnut crop measured in terms of number of branches, number of leaves, leaf area, number of pegs, canopy spread and number of nodes/plant were recorded significantly more in weed free check. This was followed by two hand weedings and hoeing at 15 DAS. The integrated methods i.e. pendimethalin (PE) at 1.0 kg/ha or fluchloralin (PPI) at 0.75 kg/ha followed by hand weeding at 15 DAS were also found effective in enhancing these growth parameters.

Yield attributes and Yield:- A field study was conducted at ARS, Chintamani in Bangalore by Shankaranarayana et al. (2000) to evolve suitable integrated weed management practices for rainfed groundnut. They found that pre-emergence spraying of pendimethalin at 1.0 kg/ha followed by 2 intercultural operations at 30 and 45 DAS and one hand weeding at 30 DAS recorded the highest pod yield and net returns with a B:C ratio of 3.26. The pod yield was at par with weed free control. Chandel and Saxena (2001) conducted a weed control experiment on loam soil of Pantnagar and reported that the highest seed yield and seed production efficiency in soybean were obtained under two HW at 30 and 45 DAS treatment followed by imazethpyr at 100 g/ha. Balsubramanian et al. (2002) in Tamil Nadu investigated the efficiency of various weed mangment practices viz., two hand weedings at 15 and 30 DAS, fluchloralin at 1.5 kg/ha, alachor at 1.5 kg/ha, fluazifop-p-butyl at 1.5 kg/ha, fluchloarlin at 1.5 kg/ha + HW at 30 DAS, alachlor at 2.0 kg/ha + HW at 30 DAS and fluazifop-p-butyl at 0.25 kg/ha + HW at 30 DAS. They reported that weed control efficiency, yield attributes and yield of sunflower were highest with the application of fluchloralin + HW T 30 DAS. Sharma and Yadav (2006) reported that two HW done at 20 and 40 DAS, pre-emergent alachlor at 1.5 kg/ha + HW at 25 DAS and pendimethalin at 0.75 kg/ha (PE) + HW at 45 DAS treatments were equally effective but significantly superior in increasing the yield attributes and seed yield of greengram in comparison to weedy check. Dhaka (2011) evaluated various weed management practices in sesame at Jobner. He noted that application of imazethapyr at 0.15 kg/ha (PE) + HW at 30 DAS resulted in the highest values of yield attributes like number of capsules/plant, seeds/capsule and test weight. It also produced the highest grain and stalk yield and fetched the maximum net returns that were significantly higher than rest of the treatments except HW twice done at 20 and 40 DAS. It was closely accompanied by alachlor at 1.5 kg/ha + HW at 20 DAS treatment. A weed control experiment in groundnut was conducted by Bhale et al. (2012) at PDKV Akola in Maharastra, comprising treatments of pendimethalin and imazethapyr along with mechanical weeding. Results indicated that pre-emergence application of pendimethalin at 1.0 kg/ha followed by one HW at 15 DAS resulted in 117.3 per cent more pods/plant unweeded control. It was followed by Imazethapyr at 75 g/ha applied at 15 days after sowing. These two treatments also witnessed significant enhancement in pod yield than unweeded control alongwith shelling% and kernel weight. Chaitanya et al. (2016) conducted a field experiment during kharif season at ARS, Chintamani in Bangalore to study the effect of pre and post emergence herbicides on weed management, yield and economics in groundnut. Results indicated revealed that application of pendimethalin 1.0 kg/ha (PE) along with post emergence application of quizalofop ethyl @ 50 g/ha at 25 DAS recorded lower weed growth and higher yield attributes and yield of groundnut as compared to farmer's practice and other weed management practices and was also economically more viable.

Nutrient concentration, uptake and quality parameters:- Kumar et al. (2003) at Hisar recorded significant reduction in N, P and K depletion by weeds with pendimethalin at 1.5 kg/ha + HW at 30 DAS and pendimethalin at 1.5 kg/ha, alone in comparison to unweeded control. These treatments also expressed their superiority over hand weeding once at 30 DAS and weedy check by enhancing the uptake of these nutrients in seed and straw of mungbean. Savu et al. (2005) carried out a weed management study in groundnut during kharif season at Raipur in Chattisgarh.They noted that application of fluchloralin at 1.0 kg/ha (PPI) followed by imazethapyr at 80 g/ha (POE) and pendimethalin at 0.90 kg/ha (PE) resulted in significantly higher pod yield and N uptake and yield of groundnut, while the uptake by weeds was minimum. Suresh et al. (2010) conducted a field experiment during rainy (kharif) seasons of 2006 and 2007 in vertisols of semi arid tropics at Hyderabad to evaluate the performance of sunflower for different weed control treatments. They recorded higher seed yield and nutrient uptake with the application of pendimethalin at 1.0 kg/ha in combination with interculturing at 21 DAS followed by hand weeding once. Dhaka (2011) reported from Jobner that remaining at par with two HW at 20 and 40 DAS, imazethapyr at 0.15 kg/ha significantly reduced the N, P and K depletion by weeds and enhanced nutrient concentration in seed and stalk and their uptake in sesame than rest of the treatments. Alachlor at 1.5 kg/ha + HW at 20 DAS was noted the next superior treatment in regard of decreasing depletion and enhancing uptake by crop. A field experiment was conducted by Gochar et al. (2016) to study the effect of cultivar and weed management on late sown groundnut.They observed that pendimethalin at 1.0 kg/ha with one hand weeding at 35 DAS significantly reduced the density and dry weight of weeds as well as and N and P depletion by individual and total weeds in comparison to pendimethalin at 1.0 kg/ha, alone and control.

Effect of sulphur: - Effect on growth:- A field experiment was conducted by Kadam et al. (2000) to evaluate the influence of planting layouts, organic manures and levels of sulphur on growth and yield of summer groundnut at MPKV, Rahuri in Mahasrastra. They found that sulphur application at 40 kg/ha recorded significantly higher plant height and total crop dry matter/plant than 20 kg/ha and control. Allam (2003) reported from Egypt that increasing levels of sulphur through gypsum upto 60 kg/ha increased the plant height, length of fruiting zone and number of branches/plant in sesame over 0, 20 and 40 kg/ha. Maity et al. (2003) conducted an experiment to evaluate to the effect of phosphorus, sulphur and planting methods on growth parameters and total yield of groundnut and sunflower at IARI, New Delhi, during the kharif 1999 and 2000. They reported that application of sulphur at 30 kg/ha registered the highest total dry matter and other growth attributes of crops than other level of sulphur. Vagharia et al. (2007) carried out a two years field study during kharif seasons of 2002 and 2003 at Junagarh on clay soil. They reported that sulphur fertilization at 50 kg/ha resulted in the significantly highest plant height, dry matter accumulation/plant and plant spread of groundnut over control. However, it showed statistical equivalence with 25 kg S/ha. Tripathi et al. (2007) conducted a two year field experiment in M.P. on clay loam soil and reported that application of sulphur at 45 kg/ha through SSP resulted in the highest plant height and number of branches/plant in sesame, followed by 45 kg S/ha applied through gypsum over control.

Yield and yield attributes:-Results of the field experiment carried out by Kadam et al. (2000) on summer groundnut at MPKV, Rahuri in Mahasrastra revealed that every increase in level of sulphur upto 40 kg/ha recorded significantly higher yield attributes, dry pod, haulm yield and protein content than 20 kg/ha and control. A three years weed management study was conducted at Ujhani (U.P.) by Chaubey et al. (2000). They found that every increase in level of sulphur upto 45 kg/ha applied through gypsum brought about significant improvement in number of pods/plant, 100-

kernels weight, shelling percentage and pod yield of groundnut over preceding levels and control. Results of the field experiment carried out by Patil et al. (2003) at PDKV, Akola during kharif season of the year 1995 and reported that application of elemental sulphur @ 20 kg/ha along with recommended dose of NP provided significantly higher kernels and haulm yield of groundnut as compared to control. Maity et al. (2003) at IARI,New Delhi noted the highest yield attributes and pod yield of groundnut when the crop was applied with sulphur at 30 kg/ha. Chitdeshwari and poongothai (2004) conducted a front line demonstration on farmer's field at Vaniyurpattinam, Arcot in Tamil Nadu to evaluate the response of groundnut to the soil application of Zn, B, S and Mo and seed treatment with Zn, B and S. They observed that pod yield increased with the combined application of Zn at 5 kg/ha + 1.0 kg B/ha + 40 kg S/ha over control to the tune of 24.2% for TMV- 7 and 14.8% for JL- 24 varieties of groundnut ,respectively. Dutta and Patra (2005) carried out an experiment at Bidhan Chandra Krishi Viswavidhyalaya, Mohanpur (W.B.) during 2000 and 2001 to study the response of sources and levels of sulphur on groundnut. They reported that sulphur fertilization at 30 kg/ha gave significantly higher number of pods/plant, shelling percentage,100-kernels weight , oil content, pod and haulm yields than 0 and 15 kg/ha. However, it showed statistical equivalence with 45 and 60 kg S/ha. A Study was conducted by Singh (2007) to evaluate the effect of variable doses of sulphur (0, 15, 30 and 45 kg/ha) potassium and calcium on pod yield of short duration summer groundnut during 2003-04 at Kanpur (U.P). Results indicated that plant height, number of filled pods/plant, kernels/pod, 100-kernels weight and pod yield improved significantly with increasing levels of sulphur upto 45 kg/ha over preceding levels. Vagharsia et al. (2007) also conducted a field experiment at Junagadh to study the response of groundnut to moisture conservation practices and sulphur nutrition. Results showed that growth, yield, quality as well as B:C ratio were significantly enhanced with the sulphur fertilization at 50 and 25 kg/ha over the control. However, these two levels were found at par with each other. Patel et al. (2009) studied the effect of irrigation schedule, sources and levels of sulphur on growth and yield groundnut. They reported that application of sulphur fertilization at 40 kg/ha gave significantly higher number of pods/plant, shelling percentage, 100- kernels weight, weight of pods/plant as well as pod yield over 0 and 20 kg S/ha. A field experiment was conducted by Ramdevputra et al. (2010) at Dhari in Gujarat to evaluate the effect of sulphur application on yield of groundnut and soil fertility under rainfed conditions. They recorded the highest pod yield as well as net realization with the application of sulphur at 18.75 kg/ha through gypsum+ 18.75 kg/ha through MOP than application of 18.75 kg S/ha alone through gypsum. However, it showed statistical similarity with the treatment involving 18.75 kg S/ha through gypsum + 18.75 kg S/ha through SOP. These treatments also resulted significant enhancement in available K_2O and S in soil after harvest.

Nutrient concentration, uptake and quality parameters:- They further reported that sulphur content in grains and stover of castor and sesame and net profit increased significantly upto 60 kg S/ha. Sahu et al. (2001) noted that the application of sulphur at 40 kg/ha through phosphogypsum produced significantly higher yield, shelling percentage, oil content, oil yield and uptake of S by groundnut than 20 kg/ha and control. Patil et al. (2003) also reported from PDKV, Akola that higher uptake of P, K and S in kernels and haulm of groundnut than control when it was applied with elemental sulphur at 20 kg/ha alongwith recommended dose of N and P.Kalaiyarasan et al. (2007) reported from Neyveli, Annamalainagar in Tamil Nadu that application of sulphur at 45 kg/ha through gypsum resulted in the highest uptake of N, P, K and S and maximum protein and oil content in groundnut. Based on their pot studies, Kumar et al. (2008) from Udaipur reported that every addition in level of sulphur upto 60 kg/ha brought about significant improvement in nutrient uptake by groundnut. The highest uptake of N, P and K as well as micro nutrients like Fe, Mn, Zn and Cu was noted at this level sulphur of that was significantly higher than 40 and 20 kg S/ha and control.

II. MATERIALS AND METHODS

The field experiment entitled "Efficacy of Herbicidal Weed Control in Groundnut (*Arachis hypogaea* L.) at Varying Levels of Sulphur" was conducted at Agronomy farm, S.K.N. College of Agriculture, Jobner during *kharif*, of 2016. The details of materials used, procedures followed and criteria adopted for evaluation of treatments during the course of investigation are described in this chapter.

Experimental site:- The experiment was conducted at Bhagwant University, Ajmer. The region falls in Agroclimatic zone III-a (Semi-arid Eastern Plain).

Climate and weather conditions:-The climate of this region is a typically semi-arid, characterized by extremes of temperature during both summers and winters. The average annual rainfall of this tract varies from 450 mm to 500 mm most of which is received during the period of July to September. During summer, temperature may go as high as 45 ^{0}C, while in winter, it may fall as low as 1.0 ^{0}C. Frost is not uncommon during winter. The relative humidity fluctuates between 52 to 92 per cent. There is hardly any rain during winter. As the climate affects the growth, yield and quality of agricultural product, it is necessary to present climatic variables in this chapter. The mean weekly weather parameters for the crop season recorded at the college meteorological observatory have been presented in table 3.1 and depicted graphically in fig. 3.1. The data revealed that *crop* season witnessed a rainfall of 281.6 mm. The mean daily maximum and minimum temperatures during the growing season of groundnut fluctuated between 29.7 to 37.7^{0}C and 14.2 to 28.2^{0}C, respectively. Similarly, mean daily relative humidity ranged between 12 to 90% cent. The average sunshine hours ranged between 5.2 to 9.4 hours/ day.

Cropping history:-The cropping history of the experimental plot for the last five years is given in table 3.2.

Table 3.2 Cropping history of experimental field

Year	Kharif	Rabi
2009-2010	Mungbean	Coriander
2010-2011	Pearlmillet	Taramira
2011-2012	Mothbean	Fallow
2012-2014	Clusterbean	Mustard
2014-2016	Groundnut*	

* Experimental crop

Soil of the experimental field:-In order to evaluate the physico-chemical properties, soil samples from 0-25 cm depth were taken from different random spots of the experimental field prior to layout. A homogeneous representative composite sample was prepared by mixing and processing of all the soil samples together and was subjected to mechanical, physical and chemical analyses. The results of these analyses along with the methods used for determination are presented in table 3.3. It is apparent from data in table 3.3 that soil of the experimental field was loamy sand in texture, alkaline in reaction, poor in organic carbon with low available nitrogen and sulphur and medium in available phosphorus and potash.

Table 3.3: Physico-chemical characteristics of the experimental field

Particulars	Values obtained	Method adopted and references
A. Mechanical analysis		
(i) Coarse sand (%)	26.5	International pipette method (Piper, 1950)
(ii) Fine sand (%)	54.15	-do-
(iii) Silt (%)	10.4	-do-
(iv) Clay (%)	8.6	-do-
(v) Textural class	Loamy sand	-do-
B. Physical analysis		
(i) Bulk density (Mg/m^3)	1.52	Method No. 30 USDA, Hand Book No. 60 (Richards, 1954)
(ii) Particle density (Mg/m^3)	2.57	Method No.39 USDA, Hand Book No.60 (Richards, 1954)
(iii) Field capacity (%)	12.50	Field method (Colmann, 1944)
(iv)Permanent wilting point (%)	2.35	Method No. 30 USDA, Hand Book No. 60 (Richards, 1954)
(v) Porosity (%)	40.86	Method No. 40 USDA, Hand Book No. 60 (Richards, 1954)
C. Chemical analysis		
(i) Available N (kg/ha)	126.3	Alkaline permanganate method (Subbiah and Asija, 1956)
(ii) Available P_2O_5 (kg/ha)	19.23	Olsen's method (Olsen *et al.*, 1954)
(iii) Available K_2O (kg/ha)	150.26	Flame photometric method (Metson, 1956)
(iv) Available Sulphur (kg/ha)	8.4	Turbidometric method (Chesnin and Yien, 1956)
(v) Organic carbon (%)	0.21	Rapid titration method (Walkley and Black, 1947)
(v) EC of saturation extract at 25^{0}C (dS/m)	1.34	Method No. 4, USDA Hand Book No. 60 (Rishards, 1954)
(vi) pH (1 : 2 soil water suspension)	8.3	Method No. 21 (b) USDA, Hand Book No. 60 (Richards,

Quality of irrigation water:-The crop was irrigated from storage tank of the college which receives water from well of Kuchyawas. A representative water sample was taken from the well and analyzed for quality parameters. The results so obtained are presented in table 3.4. Results indicated that water used for irrigation was little saline and could be safely used in light textured soils for irrigation.

Analysis of irrigation water:-

Particulars	Value	Methods adopted and references
EC_{iw} (dS/m)	0.98	Method No. 4, USDA Hand Book No. 60 (Richards, 1954)
pH	7.84	Relationship given in USDA Hand Book No. 60 (Richards, 1954)
SAR	C_3S_1	Relationship given in USDA Hand Book No. 60. (Richards, 1954)
Class (USSL)*		

*United States Salinity Laboratory, California

Experimental details:-Treatments:- The experiment comprised of six weed control treatments and four levels of sulphur thereby making 24 treatment combinations that were laid out in split plot design and replicated thrice. Weed control treatments were assigned to main plots, whereas, sulphur to sub plots. The treatments along with their symbols as allocated to the main and sub plots of the split plot design and other details are given below:

Table 3.5 Treatments with their symbols

Treatments	Symbols
(A) Weed control (Main plots)	
i. Weedy check	W_1
ii. Weed free	W_2
iii. One HW at 25 DAS	W_3
iv. Pendimethalin @ 0.75 kg/ha (Pre em.)	W_4
v. Fluazifop-p-butyl @ 0.20 kg/ha (at 25 DAS)	W_5
vi. Imazethapyr @ 100 g/ha (Pre em.)	W_6
(B) Sulphur levels (sub plots)	
i. 0 kg/ha	S_0
ii. 20 kg/ha	S_{20}
iii. 40 kg/ha	S_{40}
iv. 60 kg/ha	S_{60}

Other details:-

Season- Kharif, 2016	Total number of treatment combinations-6 x 4 =24	Replications- Three
Total number of plots-24 x 3 =72	Experimental design- Split plot design	Total number of rows-10
Plot size- (a) Gross-4.0 m x 3.0 m =12 m^2	(b) Net-3.0 m x 1.8 m= 5.4m^2	Seed rate-100 kg/ha
Planting geometry-30 cm x 10 cm	Number of rows harvested-6	Variety- RG-382

The treatments were randomly allotted to the plots as shown in plan of layout (Fig.3.2) using Fisher's random number table. (Fisher, 1950)

Treatment application:-Weed control:-Imazethapyr and pendimethalin were applied through fervent 10 SL and stomp 30 EC, respectively and Fluazifop-p-butyl through fusilade 13.4% EC. A knap-sack hydraulic sprayer was used for spraying the herbicides using a spray volume of 800 litres/ha. Imazethapyr and pendimethalin were applied as pre emergence treatment to the respective plots one day after sowing of groundnut. Whereas, fluazifop-p-butyl was applied as early post emergence treatment to the respective plots at 25 DAS. In the plots ear marked for hand weeding, the operation was done at 25 days after sowing (DAS) as per treatment.

Sulphur application: - Sulphur was applied through gypsum as per treatments at the time of sowing and mixed properly into the soil.

Details of crop rising:-The schedule of different pre and post-sowing operations carried out in the experimental field is given in table 3.6 and other details are described as under:

Field preparation:-The field was initially ploughed by disc plough followed by cross harrowing and planking to bring the field into good tilth for proper germination and establishment of seedlings. Thereafter, beds of 4.0 m x 3.0 m were prepared as per plan of layout.

Fertilizer application:-A uniform dose of 20 kg N and 40 kg P_20_5/ha was applied in furrows through urea and DAP, respectively at the time of sowing. Nitrogen was applied through urea after deducting the quantity of N supplied through DAP.

Table 3.6:-Schedule of pre and post sowing operations carried out in the experiment field

S. No.	Particulars	Date of operation	Remarks
1.	Disc ploughing and planking	31.06.2016	Tractor drawn disc plough and planker
2.	Cross ploughing	01.07.2016	Tractor drawn cultivator and planker
3.	Planking	01.07.2016	Planker
4.	Layout and preparation of beds	02.07.2016	Manually
5.	Application of fertilizers	02.07.2016	Drilling
6.	Sowing	04.07.2016	Manually by '*kera*' method
7.	Application of herbicides (i) Pendimethalin (Pre em.) (ii) Imazethapyr (Pre em.)	 05.07.2016 05.07.2016	 Foot sprayer Foot sprayer
8.	Thinning	27.07.2016	Manually
9	Irrigations (i) First irrigation (ii) Second irrigation (jjj) Third irrigation	 02.08.2016 25.09.2016 18.10.2016	 Manually Manually Manually
10.	Post em. herbicide at 25 DAS (Fluazifop-p-butyl) spray	28.07.2016	Foot sprayer
11.	Hand weeding at 25 DAS	28.07.2016	Manually
12.	Harvesting	26.10.2016	Manually
13.	Threshing and winnowing	12.11.2016	Manually

Varietal characters:-Variety RG 382 (durga) was developed at ARS, Durgapura (Rajasthan) and released during 2005. It is a semi-spreading variety recommended for cultivation in sandy and loamy soils of Rajasthan. It is a bold seeded variety with light pink color and contains 52% oil. Its shelling out turn is 67.9 percent with a 100-kernel weight of 55 g. It takes about 128-133 days to mature and gives an average yield of 22.03 quintals/hectare.

Seed treatment:-Before sowing the seed of groundnut was treated with bavistin at 2 g/kg seed and chloripyriphos 3.5 ml/kg to prevent from seed and soil borne, insects, pests and diseases.

Seed rate and sowing:-The crop was sown by '*kera*' method in the rows 30 cm apart in the furrows opened for fertilizer application using 100 kg seed/ha.

Irrigation:-The crop was irrigated three times at critical growth stages the schedule of which is presented in table 3.6.

Harvesting, threshing and winnowing:-At maturity, after leaving two border rows on each side along the length and 0.5 m along width on both sides, a net area of 3.0 m x 1.8 m was harvested separately from each plot. The harvested material of each plot was tied up in bundles, tagged and kept on threshing floor for sun drying. Dried bundles from individual plot were weighed separately to record biological yield. Threshing was done manually followed by winnowing. After cleaning, pod yield/plot was recorded and later converted into yield/hectare.

Observations for treatment evaluation:- In order to evaluate the effect of different treatments on weed and crop plants, necessary periodical observations were recorded, particulars of which are given as under:

Weed studies:-Weed flora:-Visual observation on major weed flora appeared in the experimental field were recorded time to time.

Weed density:-Weed density was taken at 35 and 70 DAS and at harvest stages from two random spots in each plot by counting the number of weeds per quadrate of 0.25 m^2 and the average was computed. In order to draw valid conclusion, the weed count data were subjected to square root transformation ($\sqrt{(x+0.5)}$) as suggested by Blackman and Roberts (1950) before subjecting to statistical analysis.

Weed dry matter:- Weeds samples from two randomly selected spots in each plot were taken at 35, 70 DAS and at harvest stages with the help of 0.25 m^2 quadrate and the average was worked out. The samples so collected were subjected to sundry for sufficient time, weighed and average was computed as dry matter kg/ha.

Weed infestation (WI):-It refers to the percentage of weeds in the composite population of weeds and crop plants and was calculated using the following formula:

$$WI(\%) = \frac{\text{Total no. of weeds in a unit area}}{\text{Total no. of weeds and crop plants the same area}} \times 100$$

Weed control efficiency (WCE):- In order to evaluate the weed control treatments for their efficacy, weed control efficiency of each treatment was calculated by using the following formula:

$$WCE(\%) = \frac{\text{Weed dry matter in weedy check plot} - \text{Weed dry matter in treated plot}}{\text{Weed dry matter in weedy check plot}} \times 100$$

Nutrient concentration:-After recording dry matter accumulation by weeds at harvest, samples were ground for estimation of N, P and K contents in weeds by employing the methods as in Table 3.7 and expressed as per cent.

Table 3.7: Methods for determination of nutrients concentration

Nutrients	Method of analysis	Reference
Nitrogen	Nesseler's reagents colorimetric method	Lindner (1944)
Phosphorus	Ammonium vanadomolybdo phosphoric acid yellow colour method	Richards (1968)
Potassium	Flame photometer method	Jackson (1973)

Nutrient depletion by weeds:-Representative samples of weed dry matter taken from each plot at harvest stage were processed and subjected to chemical analyses for their N, P, and K concentration with standard methods. The depletion of these nutrients by weeds at harvest stage was estimated by using the following formula:

$$\text{Nutrient depletion (kg/ha)} = \frac{\text{Nutrient concentration in weeds (\%)} \times \text{Weed dry matter at harvest stage (kg/ha)}}{100}$$

Crop studies:- Growth parameters:- Plant stand:-The total numbers of plants per meter row length at two randomly selected spots in each plot were counted at 20 DAS and at harvest and the average was worked out.

Dry matter accumulation:-Dry matter accumulation was also recorded at 35, 70 DAS and at harvest stages by removing plants from one meter row length from the outer two sample rows in each plot. The root portion was removed and the samples were first dried in air and then in an electric oven at 70 ^{0}C till constant weight.

Number of nodules/plant:-The total numbers of nodules/ plant were counted at 40 DAS. Five plants were randomly selected from sample rows of each plot and uprooted carefully. The soil mass embodying the roots of the plants was washed off by water and total nodules were counted. The mean value was recorded as total number of nodules/plant.

Fresh weight of nodules/plant:-The root nodules so obtained from the five plants from each plot at 40 DAS were weighed of their fresh weight.

Dry weight of nodules/plant:- The root nodules so obtained from the five plants from each plot were subjected to oven dry at 70^{o}C till a constant weight was obtained and then average was worked out.

Yield attributes and yield:- Number of pods/plant:- Five plants were randomly selected from each plot and were used for counting the number of pods/plant at harvest and their average was worked out to record pods/plant.

Number of grains/pod:-At the time of threshing, 10 pods were randomly selected from each plot and their total grain was counted to record the average number of grains/pod.

Seed index:-Groundnut kernel samples were drawn from produce of each plot. For this, 100 kernels were counted and weighed to record seed index.

Biological yield:-The weight of the thoroughly sun dried harvested produce of each net plot (3.0 m x 1.8 m) was recorded separately before threshing and expressed as biological yield in kg/ha.

Pod Yield:-After threshing, winnowing and cleaning, the producer of each plot was weighed separately and converted in terms of pod yield in kg/ha.

Haulm yield:- The haulm yield was calculated by subtracting the corresponding kernel yield from the biological yield and then converted into kg/ha.

Shelling percentage:-Well dried 200 g pods drawn from finally cleaned produce from each plot were shelled and weight of kernels was recorded and the shelling percentage was calculated with the help of following relationship:

$$\text{Shelling percentage} = \frac{\text{Kernel weight}}{\text{Pod weight}} \times 100$$

Harvest index:-Harvest index (HI) was computed by using the formula outline by Singh and Stoskopf (1971).

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

Weed competition index (WCI):-This was calculated by using the formula given by Yadav and Mishra (1982).

$$\text{WCI (\%)} = \frac{\text{Pod yield of weed free plot} - \text{pod yield of treated plot}}{\text{Pod yield of weed free plot}} \times 100$$

Nutrient concentration, uptake and quality attributes:- Nutrient concentration in kernel and haulm Nitrogen:- Representative samples of groundnut kernel and haulm taken at harvest stage were oven dried, ground in Willey mill and analysed for their N concentration. Nitrogen was estimated, by colorimetric method (Snelll and Snell, 1949). Samples were digested with sulphuric acid and treated with hydrogen peroxide to remove black colour. Nesseler's reagent was used to develop colour. The results so obtained were expressed as per cent N concentration on dry weight basis.

Phosphorus:-Phosphorus concentration in kernel and haulm were determined by "Vanadomolybdophosphate" Yellow colour method. Digestion of samples was done by triacid mixture. Ammonium molybdate-ammonium vandate solution was used to develop colour and resultant intensity of colour was measured by Klett summerson photoelectric colorimeter and expressed as per cent phosphorus concentration on dry weight basis (Jackson,1973).

Sulphur:- Sulphur was estimated by turbidimetric method (Tabatabai and Bremmer, 1970). The plant samples (pod and haulm) were digested in diacid mixture and barium chloride solution was used for development of turbidity. The resultant turbidity was measured on spectrophotometer at 420 nm wavelength. The sulphur concentration was calculated and represented in percentage.

Total nutrient uptake:-The total uptake of nitrogen, phosphorus and sulphur was computed from N, P and S concentration in kernel and haulm at harvest using following relationship:

Total uptake (kg/ha)=	Nutrient conc. in kernel (%) x	pod yield (kg/ha)	+	Nutrient conc. in haulm (%) x	Haulm Yield (kg/ha)
	100				

Protein content in kernel:-Protein content in grain was calculated from the per cent nitrogen in the kernel multiplied by the factor 6.25 (A.O.A.C., 1960) and expressed as per cent protein content.

Nutrient use efficiency:-Agronomic efficiency, apparent recovery and physiological efficiencies of sulphur was calculated using following formulae (Singh and Singh, 2012)

$$\text{Agronomic efficiency of S } (AE_s) = \frac{Y_s - Y_c}{\text{S applied}}$$

$$\text{Apparent recovery (\%) of S } (RE_s) = \frac{U_s - U_c \times 100}{\text{S applied}}$$

$$\text{Physiological Efficiency of S } (PE_s) = \frac{Y_s - Y_c}{U_s - U_c}$$

Where:-Y = Yield of cluster bean (kg/ha), U = Uptake of S by crop (kg/ha), s and c = Yield/uptake of crop under S applied treatment and under control, respectively (kg/ha).

Oil content (%):-Oil content in the kernel was determined by Soxhlet's apparatus using petroleum ether (60-80 ^{0}C) as an extractant (A.O.A.C., 1960).

Oil yield:-The oil yield (kg/ha) was calculated by multiplying per cent oil content with respective kernel yield.

Statistical analysis: - The experimental data recorded for weeds growth, yield and other characters were statistically analysed by Fisher's 'Analysis of Variance' technique (Fisher, 1950). Appropriate standard error for each of the factor was worked out. Significance of differences among treatment effects was tested by "F" test as described by Panse and Sukhatme (1985) for split plot design. Critical difference (CD) was worked out wherever the difference was found significantly at 5.0 or 1.0 per cent level of significance. The 'Analyses of Variance' of different components for all the parameters discussed are given in the annexure at the end.

Correlation and regression studies:-To assess the relationship, correlation and regression coefficients between kernel yield of groundnut (Y) and the independent variables (X) such as weed dry matter, crop dry matter accumulation, yield attributes, nutrient depletion by weeds, nutrient uptake by crop were computed using the method given by Snedecor and Cochran (1968). The regression equations were also fitted and tested for significance.

Economics:-The economics of treatments is the prime important consideration before making any recommendation to the farmers for its adoption. Hence, to evaluate the effectiveness and profitability of the treatments, comprehensive economics including net returns (`/ha) and B: C ratio was calculated so that the most effective and remunerative treatment could be recommended. The details of calculation with prevailing market prices of the inputs and produce are given in the annexure at the end.

Response studies:-To describe the relationship of pod yield (Y) as a function of the simple effect of sulphur fertilization (X), correlation and regression studies were under taken. Response equation was fitted to the yield data to describe them mathematically. The following equation proved to be the best fit:

$$Y = b_0 + b_1X + b_2X^2$$

Where:-Y= Expected yield (kg/ha), X= Unit of S level (kg/ha), b_0= Constant, b_1 and b_2 = Regression coefficient

After fitting response curve, optimum dose of S was worked out by the following formula:

$$X_{opt} = \frac{1}{2\,b_2} \times \frac{Q}{p} - b_1$$

Where:-X_{opt} = Optimum dose of S, P = Price per kg of pod yield (Rs), Q= Cost per kg S (Rs), b_1 and b_2 = Coefficients of response equation.

Table 3.1 Mean weekly weather parameters recorded during crop season (Kharif, 2016)

SMW No.	1) Period		Temperature (^{0}C)		Mean R.H. (%)	Evaporation (mm/day)	Bright sunshine (hrs)	Rainfall (mm)
	From	2) To	Maximum	Minimum				
27	25.06.2016	01.07.2016	37.7	28.2	53	11.2	08.9	012.4
28	02.07.2016	08.07.2016	35.3	26.3	12	06.2	06.9	031.8
29	09.07.2016	15.07.2016	33.4	24.8	75	05.3	05.8	004.7
30	16.07.2016	22.07.2016	33.7	25.4	78	04.9	05.9	004.3
31	23.07.2016	29.07.2016	32.3	25.9	81	03.9	07.4	002.6
32	30.07.2016	05.08.2016	31.5	25.2	85	03.8	07.1	002.8
33	06.08.2016	12.08.2016	30.0	24.4	89	03.1	05.7	003.3
34	13.08.2016	19.08.2016	29.7	24.5	90	03.2	03.8	003.5
35	20.08.2016	26.08.2016	31.5	23.7	81	03.5	05.9	003.3
36	27.08.2016	02.09.2016	32.9	22.8	70	05.8	08.9	004.6
37	03.09.2016	09.09.2016	33.9	20.2	61	06.7	09.6	004.3
38	10.09.2016	16.09.2016	37.1	22.7	55	08.0	08.4	002.5
39	17.09.2016	23.09.201	35.5	21.7	63	06.8	08.2	003.1

		6						
40	24.09.2016	30.09.2016	31.3	23.7	79	04.8	06.4	003.4
41	01.10.2016	07.10.2016	31.5	22.7	72	04.2	07.4	003.4
42	08.10.2016	14.10.2016	32.1	21.8	75	04.3	05.2	003.3
43	15.10.2016	21.10.2016	34.2	18.2	55	04.6	09.4	002.1
44	22.10.2016	28.10.2016	32.5	14.2	51	04.9	09.0	001.7

III. RESULTS

Results of the field experiment entitled "Efficacy of Herbicidal Weed Control in Groundnut (*Arachis hypogaea* L.) at Varying Levels of Sulphur" conducted during *kharif,* 2015 at Agronomy farm, Bhagwant University Ajmer (Rajasthan) are being presented in this chapter. Data on growth of weeds and crop, yield and quality parameters periodically recorded during the course of investigation were statistically analyzed to test their significance. The analyses of variance for all these components have been presented in annexure at the end. Results of the main effects and significant interactions have been presented and illustrated graphically for better understanding of important trends, wherever felt necessary.

Weed studies:- Weed survey:-Major weed species that appeared during the crop season along with their taxonomical details have been mentioned in table 4.1. Survey of the experimental field revealed that the weedy check plots of groundnut were heavily invaded by annual dicot weeds chiefly *Amaranthus spinosus* and *Amaranthus viridis* immediately with the crop emergence. *Phyllanthus niruri*, *Digera arvensis, Euphorbia hirta, Trianthema portulacastrum* and *Verbesina encelioides* were another dicot weeds found to infest the experimental field. *Cyperus rotundus* and *Cynodon dactylon* appeared to be the prominent monocot weed species, though; the population of these weeds was low.

Weed density:-Weed control: A perusal of data presented in table 4.2 indicated that all the treatment practiced for weed control in groundnut recorded significantly lower weed density at all the stages of observation in comparison to weedy check. After weed free, the lowest density at all the stages (6.47, 5.35 and 4.38 per 0.25 m^2) was recorded under pendimethalin at 0.75 kg/ha (PE) treatment. Remaining at par with one HW at 25 DAS, it reduce the weed density by 22.8, 42.4 and 86.1 per cent at 35 DAS; 36.3, 49.1 and 86.3 per cent at 70 DAS and 42.9, 55.0 and 84.8 per cent at harvest in comparison to imazethapyr at 100 g/ha, fluazifop-p-butyl at 0.20 kg/ha and weedy check treatments, respectively. Pre emergence application of imazethapyr at 100 g/ha also registered 81.8, 78.5 and 73.6 per cent decline in density of weeds at these stages than weedy check, respectively. Fluazifop-p-butyl at 0.20 kg/ha, though represented significant reduction in weed density than weedy check but was found less effective than above mentioned treatments.

Sulphur levels: It is further apparent from the data (Table 4.2) that different levels of S did not result any significant variation in weed density at any stage of crop growth.

Table:- 4.1. Important weed flora of the experimental field

S.No.	Botanical Name	Common Name	English Name	Family	Growth habit
1.	*Boerhavia diffusa* L.	Bish khapra	Spiderling	Nyctaginaceae	ARS
2.	*A. viridis* L.	Jangli Chaulai	Slender amaranthus	Amaranthaceae	ADRS
3.	*Amaranthus spinosus* L.	Kataili chaulai	Spiny amarthus	Amaranthaceae	ADRS
4.	*Dactyloctenium aegyptium* L.	Makragrass	Crowfootg rass	Poaceae	ARV
5.	*Tribulus terrestris* L.	Bhankri	Puncturevine	zygophyllaceae	ARV & RS
6.	*Cyperus rotundus* L.	Motha	Purple nutsedge	Cyperaceae	PMRS
7.	*Leucas aspera*	Gumma	Leucas	Labiatae	ARV
8.	*Phyllanthus niruri* Hook.	Bhuinanwla	Hazardana	Euphorbiaceae	ADRS

9.	*Digera arvensis*	Lahsua	Digera	Amaranthaceae	ARV
10.	*Trianthema portulacastrum* L.	Patharchatha	urslane, Carpet weed,	Azoaceae	ADRS
11.	*Cynodon dactylon* L.	Doob grass	Bermuda graass	Poaceae	PMRS & RV
12.	*Cenchrus biflorus*	Berboot	Sand bur	Poaceae	AMRS
13.	*Euphorbia hirta* L.	-	Bari dudhi	Euphorbiaceae	ADRS
14.	*Convolvulus arvensis*	Hirankhuri	Field bind weed	Convolvulaceae	PRV
15.	*Verbesina encelioides* Benth	-	Golden crown	Asteraceae	ADRS
16.	*melina benghalensis* L.	Moria bati	Dayflower	Commelinaceae	ARV
17.	*Pedalium murex* L.	Gokhru	Puncturevine	Zygophyllaceae	ARS
18.	*Launea asplenifolia* (L.)	Jangli gobhi	Wild gobhi	Asteraceae	AMRS
19.	*Sorghum helpense*	Baru	Jhonson grass	Poaceae	PRV
20.	*Portulaca oleracea*	Grass	Purslene	Poaceae	ARS
21.	*Elevsine indica*	Grass	Goose grass	Poaceae	ARS

A = Annual M = Monocot RS = Reproduction by seed
P = Perennial D = Dicot RV = Reproduction by vegetative means

Weed infestation:- Weed control:- All the weed control treatments differed significantly in influencing the weed infestation at different stages of observation (Table 4.2). Unrestricted growth of weeds under weedy check treatment resulted in infestation of crop with weeds as high as 51.1, 48.3 and 45.1 per cent at 35 DAS, 70 DAS and at harvest stage, respectively. On the other hand, pendimethalin at 0.75 kg/ha registered the lowest weed infestation values (26.3, 24.5 and 23.5 per cent) after weed free treatment, at these three stages. One HW at 25 DAS was also found equally effective in reducing the weed infestation wherein, weed infestation of 28.4, 26.0 and 26.2 per cent at these three stages was recorded. It was followed in the order of imazethapyr a @ 100 g/ha (PE) and fluazifop-p-butyl at 0.20 kg/ha applied at 25 DAS that registered 17.6 and 15.2 per cent lower weed infestation at 70 DAS and 16.3 and 13.2 per cent at harvest stage of crop than weedy check treatment, respectively.

Sulphur levels:- Result further revealed that different levels of S fertilization did not bring any significant variation in weed infestation at any stages of crop growth.

Table 4.2 Effect of weed control and sulphur levels on density and infestation of weeds at different stages of crop

Treatments	Weed dry matter (kg/ha)		
	35 DAS	70 DAS	At harvest
Weed control			
Weedy check	946.0	2284.9	2729.0
Weed free	0.0	0.0	0.0
One HW at 25 DAS	149.8	378.3	546.8
Pendimethalin @ 0.75 kg/ha	140.2	324.3	457.9
Fluazifop-p-butyl @ 0.20 kg/ha	199.8	655.5	892.8
Imazethapyr @ 100 g/ha	174.3	498.8	702.1
SEm±	7.3	20.2	29.6
CD (P = 0.05)	22.9	63.5	93.3
CV (%)	9.4	10.1	11.5
Sulphur levels (kg/ha)			
0	254.2	586.9	760.3
20	267.1	697.9	898.5
40	274.1	723.2	936.7
60	278.0	753.0	956.8
SEm±	4.5	12.9	19.6
CD (P = 0.05)	12.0	34.3	52.0
Interaction (WxS)	NS	Sig.	Sig.
CV (%)	7.2	7.9	9.3

NS= Non significant, Sig. = Significant

Weed dry matter:-Weed control:- It is apparent from the data presented in table 4.3 and fig. 4.1 that all the weed control treatments differed significantly in their effect on periodical weed dry matter production. After weed free, pre-emergence application of pendimethalin at 0.75 kg/ha treatment recorded the significantly lowest weed dry matter of 140.2, 324.3 and 457.9 kg/ha at 35, 70 DAS and harvest stages, respectively. However, it was found at par with one HW at 25 DAS. Pendimethalin at 0.75 kg/ha represented 35.0, 50.5 and 85.8 per cent reduction in weed dry matter at 70 DAS and 34.7, 48.8 and 83.2 per cent at harvest stage over imazethapyr at 100 g/ha, fluazifop-p-butyl at 0.20 kg/ha and weedy check treatments, respectively. The corresponding decrease due to one HW at 25 DAS treatment was 24.1, 42.2 and 83.5 per cent at 70 DAS and 22.1, 39.0 and 79.9 per cent at harvest stage. Imazethapyr at 100 g/ha was found the next superior treatment in reducing weed dry matter. It registered weed dry matter of 498.8 and 702.1 kg/ha at 70 DAS and at harvest stages thereby reducing it to the extent of 23.9 and 78.1 per cent at 70 DAS and 21.3 and 72.6 per cent at harvest stages over fluazifop-p-butyl at 0.20 kg/ha and weedy check treatments, respectively. Fluazifop-p-butyl at 0.20 kg/ha also reduced the weed dry matter to the tune of 78.9 per cent at 35 DAS, 71.3 per cent at 70 DAS and 67.2 per cent at harvest stage over weedy check treatment.

Sulphur levels:- It is obvious from the data presented in table 4.3 and fig. 4.1 that increasing the level of sulphur from 0 to 20 kg/ha significantly increased the periodical weed dry matter than control. Application of sulphur at 60 kg/ha produced the highest weed biomass of 278.0, 753.0 and 956.0 kg/ha at 35 and 70 DAS and harvest stages that was 4.0, 7.9 and 6.5 per cent higher than 20 kg S/ha and 9.4, 28.3 and 25.8 per cent than control at these three stage, respectively. However, it remained at par with 40 kg S/ha.

Interaction:- Combined effect of weed control and S fertilization was also found to significantly influence the weed dry matter production at 70 DAS and at harvest stages (Table 4.3.1 and fig.4.2). Results indicated that higher levels of S fertilization favoured more weed dry matter production under weedy check treatment. Weedy check along with S fertilization at 60 kg/ha registered the highest weed dry matter of 2492.4 and 2940.1 kg/ha at 70 DAS and harvest stages which was significantly higher than lower levels except 40 kg S/ha. Significant increase in weed dry matter under fluazifop-p-butyl at 0.20 kg/ha treatment was noted upto 20 kg S/ha. Rest of the weed control treatments showed poor response to increase in S levels though, the highest dry matter was recorded at 60 kg S/ha.

Table 4.3-Effect of weed control and sulphur levels on periodical weed dry matter production

Treatments	**Weed dry matter (kg/ha)**		
	35 DAS	**70 DAS**	**At harvest**
Weed control			
Weedy check	946.0	2284.9	2729.0
Weed free	0.0	0.0	0.0
One HW at 25 DAS	149.8	378.3	546.8
Pendimethalin @ 0.75 kg/ha	140.2	324.3	457.9
Fluazifop-p-butyl @ 0.20 kg/ha	199.8	655.5	892.8
Imazethapyr @ 100 g/ha	174.3	498.8	702.1
SEm±	7.3	20.2	29.6
CD (P = 0.05)	22.9	63.5	93.3
CV (%)	9.4	10.1	11.5
Sulphur levels (kg/ha)			
0	254.2	586.9	760.3
20	267.1	697.9	898.5
40	274.1	723.2	936.7
60	278.0	753.0	956.8
SEm±	4.5	12.9	19.6
CD (P = 0.05)	12.0	34.3	52.0
Interaction (WxS)	NS	Sig.	Sig.
CV (%)	7.2	7.9	9.3

NS= Non significant, Sig. = Significant

Weed control efficiency:-There was a great variation in the extent to which the weeds were controlled by different weed control treatments (Table 4.4). Pre emergence application of pendimethalin at 0.75 kg/ha was found the most superior treatment which controlled the weeds to the extent of 85.18, 85.81 and 79.96 per cent at 35 and 70 DAS and harvest stages of crop, respectively in comparison to weedy check. It was very closely accompanied by one HW at 25 DAS treatment that registered higher weed control efficiencies of 84.17, 83.44 and 79.96 per cent at these three stages. Imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha also registered higher weed control efficiencies of 81.58 and 78.88; 78.16 and 71.31, and 74.27 and 67.28 per cent at these three stages of crop growth.

Crop studies:- Growth attributes:-Plant stand:-Data presented in table 4.5 revealed that weed control treatments as well as levels of sulphur could not bring significant variation in plant stand of groundnut upto the level of significance at both stages of observation.

Dry matter accumulation:-Weed control:- A critical examination of data presented in table 4.5 and fig. 4.3 indicated that all the measures adopted for weed control in groundnut produced significantly higher crop dry matter than weedy check at all the stages. Application pendimethalin at 0.75 kg/ha recorded the highest dry matter of 25.86, 196.72 and 466.80 g/m row length at 35 and 70 DAS and at harvest stages which showed statistical equivalence with weed free treatment. It registered 21.3, 35.3 and 78.13 per cent increase in crop dry matter at 70 DAS and 17.3, 31.5 and 58.5 per cent at harvest stage than with imazethapyr at 100 g/ha, fluazifop-p-butyl at 0.20 kg/ha and weedy check treatments, respectively. However, it was found at par with one HW at 25 DAS. The corresponding increase recorded due to one HW treatment was 15.8, 29.1 and 70.0 per cent at 70 DAS and 10.5, 23.9 and 49.3 per cent at harvest stage.

Table 4.4 -Effect of weed control on weed control efficiency at different stages of the crop

Treatments	Weed control efficiency (%)		
	35 DAS	70 DAS	At harvest
Weedy check	-	-	-
Weed free	100.00	100.00	100.00
One HW at 25 DAS	84.17	83.44	79.96
Pendimethalin @ 0.75 kg/ha	85.18	85.81	83.22
Fluazifop-p-butyl @ 0.20 kg/ha	78.88	71.31	67.28
Imazethapyr @ 100 g/ha	81.58	78.16	74.27

Sulphur levels: It is also apparent from the data (Table 4.5 and Fig. 4.3) that progressive increase in level of S produced significantly higher amount of crop dry matter upto 40 kg/ha at 35 DAS and 60 kg/ha at 70 DAS and at harvest stages over lower levels and control. The per cent increase in dry matter due to application of 60 kg S/ha was 2.8, 12.7 and 111.6 at 35 DAS; 4.3, 26.7 and 78.2 at 70 DAS and 17.4, 52.2 and 125.8 at harvest stage over 40 and 20 S/ha and control, respectively.

Table 4.5-Effect of weed control and sulphur levels on plant stand and crop dry matter accumulation at different stages

Treatments	Plant stand/m row length		Dry matter accumulation/m row length (g)		
	20 DAS	At harvest	35 DAS	70 DAS	At harvest
Weed control					
Weedy check	9.1	8.8	13.15	110.43	294.41
Weed free	10.3	9.7	26.79	199.61	495.15
One HW at 25 DAS	9.9	9.2	23.96	177.76	439.77
Pendimethalin @ 0.75 kg/ha	10.2	9.6	25.86	196.72	466.80
Fluazifop-p-butyl @ 0.20 kg/ha	9.4	9.1	18.54	145.38	354.90
Imazethapyr @ 100 g/ha	9.6	9.4	22.12	162.07	397.90
SEm±	0.32	0.28	0.67	4.26	11.55
CD (P = 0.05)	NS	NS	2.10	13.42	36.41
CV (%)	11.54	10.30	10.62	8.92	9.81
Sulphur level (kg/ha)					
0	9.5	8.7	12.33	112.13	244.99
20	9.7	9.2	23.14	157.72	363.28
40	9.8	9.5	25.38	191.58	471.15
60	9.9	9.6	26.10	199.88	553.20
SEm±	0.19	0.18	0.39	2.39	7.11
CD (P = 0.05)	NS	NS	1.05	6.33	18.88
Interaction (WxS)	NS	NS	Sig.	Sig.	Sig.
CV (%)	8.12	8.20	7.70	6.12	7.39

NS= Non significant, Sig. = Significant

Interaction:-Interactive effect of weed control treatments and sulphur fertilization was also found significant in regard of influencing crop dry matter accumulation at all the stages (Table 4.5.1). Results showed that with the advancement in crop stages dry matter of crop increased significantly under all the weed control treatments when they were integrated with higher levels of sulphur. At 35 DAS stage, response was noted upto 20 kg/ha under all the weed control treatments. Whereas, at 70 DAS, it was observed upto 40 kg S/ha. At harvest stage integration weed control treatment with 60 kg S/ha recorded significant enhancement in crop dry matter over lower levels. The highest crop dry matter was obtained when weed free treatment was integrated with 60 kg S/ha (W_2S_{60}). However, it was found at par with pendimethalin at 0.75 kg/ha along with 60 kg S/ha (W_4S_{60}). W_4S_{60} also showed statistical equivalence with W_3S_{60} treatment combination at harvest stage of the crop.

Number of nodules/plant:-Weed control:- It is obvious from the data presented in table 4.6 that all the weed control treatments significantly improved the number of nodules/plant recorded at 40 DAS stage in comparison to weedy check (Table 4.6). Weed free treatment attained the highest number of 64.28 nodules/plant among all the treatments. However, it was found statistically at par with pendimethalin at 0.75 kg/ha and one HW at 25 DAS treatments, wherein 63.41 and 61.42 nodules/plant, respectively were recorded. These three treatments improved the number of nodules/plant by margin of 40.7, 38.9 and 34.4 per cent, respectively in comparison to weedy check. One HW at 25 DAS was also found at par with pre emergence application of Imazethapyr at 100 g/ha treatment with 57.56 nodules/plant. Imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha treatment were noted to have 26.0 and 15.2 per cent more nodules/plant than weedy check treatment.

Sulphur levels:-A further reference to data presented in table 4.6 revealed that increasing levels of sulphur fertilization upto its highest level of 60 kg/ha brought about significantly higher number of nodules/plant over preceding levels. This level of S improved the number of nodules/plant to extent of 4.7, 18.2 and 38.3 per cent over 40 and 20 kg S/ha and control, respectively.

Table 4.6 Effect of weed control and sulphur levels on number and weight of nodules/plant at 40 DAS

Treatments	Number of nodules/plant	Weight of nodules/plant (mg)	
		Fresh weight	Dry weight
Weed control			
Weedy check	45.68	134.98	67.66
Weed free	64.28	195.20	93.71
One HW at 25 DAS	61.42	188.97	87.24
Pendimethalin @ 0.75 kg/ha	63.41	192.96	90.58
Fluazifop-p-butyl @ 0.20 kg/ha	52.65	158.21	74.84
Imazethapyr @ 100 g/ha	57.56	177.97	78.90
SEm±	1.49	3.90	1.88
CD (P = 0.05)	4.69	12.28	5.93
CV (%)	8.97	7.73	7.94
Sulphur levels (kg/ha)			
0	47.18	142.18	67.57
20	55.21	167.42	79.14
40	62.34	190.48	88.73
60	65.27	198.78	93.18
SEm±	0.92	3.12	1.42
CD (P = 0.05)	2.45	8.28	3.77
CV (%)	6.79	7.57	7.32

Fresh and dry weight of nodules/plant:-Weed control: Fresh and dry weight of nodules/plant was also influenced by different weed control treatments in the same manner as number of nodules/plant (Table 4.6). Weed free, pendimethalin at 0.75 kg/ha and one HW at 25 DAS treatments were found promising and statistically similar treatments that recorded 195.20, 192.96 and 188.97 mg fresh weight of nodules/plant thereby increasing it to the extent of 44.7, 43.0 and 40.0 per cent, respectively than weedy check. The corresponding increase in dry weight of nodules/plant due to these treatments was 38.6, 33.9 and 29.0 per cent. Imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha also recorded 31.9 and 17.2 per cent increase in fresh weight and 16.7 and 10.7 per cent in dry weight of nodules/plant as compared to weedy check treatment and thus found at par with each other.

Sulphur levels:- It is also evident from the data that progressive increase in levels of S upto its highest levels resulted significant improvement in fresh and dry weight of nodules/plant over preceding levels (Table 4.6). It recorded the highest fresh and dry weight of nodules (198.78 and 93.18 /plant) which was 4.3 and 5.0 per cent more than 40 kg S/ha; 18.7 and 17.8 per cent than 20 kg/ha and 39.9 and 37.9 per cent than control, respectively.

Yield attributes and yield:-Number of pods/ plant:-Weed control: A critical examination of the data presented in table 4.7 and fig. 4.4 indicated that all the weed control treatments attained significantly more number of pods/plant than unweeded control. After weed free, application of pendimethalin at 0.75 kg/ha (PE) recorded the highest pods/plant (19.94) that were significantly more than rest of the treatments except one HW at 25 DAS (18.89). These two treatments enhanced the number of pods/plant to the tune of 13.7 and 11.6 per cent over imazethapyr at 100 g/ha, 38.7 and 36.19 per cent over fluazifop-p-butyl at 0.20 kg/ha and 95.0 and 91.3 per cent over weedy check treatments, respectively. Registering 71.4 and 40.5 per cent more number of pods/plant than weedy check, imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha were noted to be the next superior treatments in this regard.

Sulphur levels:- Sulphur fertilization in groundnut also significantly improved the number of pods/plant (Table 4.7 and fig. 4.4). Application of S at 60 kg/ha recorded the highest number of 20.84 pods/plant that were 8.3, 27.5 and 112.2 per cent higher than recorded under 40 and 20 kg S/ha and control, respectively.

Interaction:- Combined effect of weed control treatments and sulphur levels was also found significant in influencing number of pods/plant (Table 4.7.1). Significant enhancement in pods/plant under weedy check and fluazifop-p-butyl treatments was noticed when they were integrated with 20 kg S/ha. Whereas in rest of the weed control treatments, number of pods/plant increased significantly up to 40 kg S/ha. Integration of 60 kg S/ha along with weed free and pendimethalin at 0.75 kg/ha were found the most superior and equally effective treatment combinations in enhancing pods/plant (25.9 and 24.2). W_2S_{40}, W_3S_{60} and W_4S_{40} were found the next superior treatment combinations for obtaining more number of pods/plant.

Table 4.7 Effect of weed control and sulphur levels on yield attributes of groundnut

Treatments	Number of pods/ plant	Number of karnels/ pod	Seed index (g)
Weed control			
Weedy check	9.87	1.64	52.54
Weed free	20.59	2.25	71.09
One HW at 25 DAS	18.89	2.09	65.90
Pendimethalin @ 0.75 kg/ha	19.24	2.16	68.39
Fluazifop-p-butyl @ 0.20 kg/ha	13.87	1.82	57.32
Imazethapyr @ 100 g/ha	16.92	1.96	61.93
SEm$\pm$	0.47	0.05	1.42
CD (P = 0.05)	1.49	0.15	4.48
CV (%)	9.88	8.13	7.84
Sulphur levels (kg/ha)			
0	9.82	1.66	55.23
20	16.34	1.96	61.60
40	19.24	2.13	65.63
60	20.84	2.20	68.98
SEm$\pm$	0.34	0.04	1.11
CD (P = 0.05)	0.89	0.09	2.94
Interaction WxS)	Sig.	NS	NS
CV (%)	8.60	7.58	7.47

Number of kernels/pods:-Weed control:- Data pertaining to the effect of different weed control treatments on number of kernels/pod presented in table 4.7 and fig. 4.4 showed that all the treatments recorded significantly more number of kernels/pod than weedy check treatment. After weed free, the highest number of 2.16 kernels/pod was achieved under pendimethalin at 0.75 kg/ha that was statistically at par with weed free and one HW at 25 DAS. It registered 10.2, 18.6 and 31.7 per cent increase in kernels/pod over imazethapyr at 100 g/ha, fluazifop-p-butyl at 0.20 kg/ha and weedy check treatments, respectively. Per cent improvement in kernels/pod rendered by one HW at 25 DAS was 14.8 and 27.4 per cent over fluaziffop-p-butyl at 0.20 kg/ha and weedy check treatments which also showed statistical similarity with imazethapyr at 100 g/ha treatment.

Table-4.7.1Combined effect of weed control and sulphur levels on number of pods/plant

Treatments	S_0	S_{20}	S_{40}	S_{60}
W_1 - Weedy check	5.9	9.7	11.5	12.4
W_2 - Weed free	12.2	20.3	23.9	25.9
W_3 - One HW at 25 DAS	11.2	18.6	21.9	23.8
W_4 - Pendimethalin @ 0.75 kg/ha	11.4	19.0	22.3	24.2
W_5 - Fluazifop-p-butyl @ 0.20 kg/ha	8.2	13.7	16.1	17.5
W_6 - Imazethapyr @ 100 g/ha	10.0	16.7	19.7	21.3
For S at same level of W				
SEm±				0.8
CD (P=0.05)				2.4
For W at same or different levels of S				
SEm±				0.60
CD (P=0.05)				1.71

Sulphur levels:- Perusal of data (Table 4.7 and fig. 4.4) revealed that application of sulphur at 40 kg/ha registered 8.6 and 28.3 more number of kernels/pod in comparison to 20 kg S/ha and control, respectively. Further increase in its level to 60 kg/ha, though, maximized the number of kernels/pod (2.20), yet, it was found at par with 40 kg S/ha.

Seed index:-Weed control:- Seed index was also influenced significantly due to different weed control treatments (Table 4.7 and fig. 4.4). After weed free, pendimethalin at 0.75 ka/ha and one HW at 25 DAS were found to be the most superior treatments in this regard. These treatments resulted a significant increase of 19.3 and 14.9 per cent over fluazifop-p-butyl at 0.20 kg/ha and 30.1 and 25.4 per cent over weedy check treatments. Imazethapyr at 100 g/ha was the next superior treatment that also increased the seed index by margin of 17.9 per cent over weedy check treatment.

Sulphur levels:- It is further evident from the data (Table 4.7 and Fig. 4.4) that seed index of groundnut was significantly improved due to successive increase In level of sulphur over preceding levels. Sulphur fertilization at 60 kg/ha recorded the highest seed index of 68.98 g thereby resulting a per cent increase of 5.1, 11.9 and 24.8 per cent over 40, 20 and 0 kg S/ha, respectively.

Pod yield:-Weed control:-Perusal of data presented in the table 4.8 and fig. 4.5 indicated that all the weed control treatments significantly increased the pod yield of groundnut over weedy check. After weed free (1971 kg/ha), the maximum pod yield of 1854 kg/ha was obtained with application of pendimethalin at 0.75 kg/ha (PE) treatment. It resulted a remarkable increase 19.2, 38.0 and 89.7 per cent over imazethapyr at 100 g/ha (PE), fluazifop-p-butyl at 0.20 kg/ha and weedy check treatments, respectively. However, it showed statistical equivalence with one HW at 25 DAS (1750 kg/ha) which represented a corresponding increase of 12.54, 30.3 and 12.54 per cent. Imazethapyr at 100 g/ha increased the pod yield by magnitude of 212 and 578 kg/ha in comparison to fluazifop-p-butyl at 0.20 kg/ha and weedy check treatments, respectively. Application of fluazifop-p-butyl at 0.20 kg/ha at 25 DAS also recorded a significant increase of 37.4 per cent over weedy check, yet proved inferior to above mentioned treatments.

Sulphur levels:-It is also evident from the data (Table 4.8 and Fig. 4.5) that pod yield of groundnut was significantly improved due to successive addition in level of sulphur over preceding levels. Application of sulphur at 60 kg/ha recorded the highest yield of 1999 kg/ha thereby resulting a per cent increase of 8.9, 28.3 and 120.2 over 40 and 20 kg S/ha and control, respectively.

Interaction:-Combined effect of weed control and sulphur fertilization was also noted to significantly influence the pod yield of groundnut (Table 4.8.1 and Fig. 4.6). Results indicated that weed free and pendimethalin at 0.75 kg/ha treatments recorded significantly higher pod yield with every increase in level of S upto 60 kg/ha over preceding levels. In rest of the treatments, significant increase was found upto 40 kg S/ha, only. Weed free treatment along with 60 kg S/ha (W_2S_{60}) produced the highest pod yield (2502 kg/ha) and proved superiority over rest of the treatment combinations except pendimethalin at 0.75 kg/ha plots applied with 60 kg S/ha (2353 kg/ha). It was followed in the order of W_2S_{40}, W_3S_{60} and W_4S_{40} combinations. Unfertilized weedy check plots (W_1S_0) recorded the lowest pod yield of only 563 kg/ha.

Haulm yield:-Weed control:- A reference to the data (Table 4.8 and Fig. 4.5) indicated that haulm yield of groundnut was influenced by weed control treatments in the same manner as in case of pod yield. The maximum haulm yield of 3675 kg/ha was obtained with the weed free treatment. It was closely accompanied by pendimethalin at 0.75 kg/ha (3456 kg/ha) and one HW at 25 DAS (3259 kg/ha) treatments. Remaining at par with each other, these two treatments enhanced the haulm yield to the extent of 20.7 and 13.8 per cent over imazethapyr at 100 g/ha; 33.4 and 25.9 per cent over fluazifop-p-butyl at 0.20 kg/ha, and 93.2 and 82.2 per cent over weedy check treatments, respectively. Witnessing the quantitative increase of 1076 and 802 kg/ha over weedy check, imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha were found the next superior treatments in this regard.

Sulphur levels:-It is also apparent from the data presented in table 4.8 and Fig. 4.5 that every increase in level of sulphur up to 60 kg/ha produced significantly higher haulm yield of groundnut in comparison to lower levels. It recorded the haulm yield of 3679 kg/ha that was 7.2, 31.9 and 98.3 per cent higher than obtained with 40 and 20 kg S/ha and control, respectively.

Interaction:-Interactive effect of weed control and S fertilization was also found significant in influencing the haulm yield of groundnut (Table 4.8.1). Results revealed that weed free combined with 60 kg S/ha (W_2S_{60}) and pendimethalin at 0.75 kg/ha (PE) in conjunction with 60 kg S/ha (W_4S_{60}) yielded significantly higher haulm yield (4597 and 4327 kg/ha) than most of the treatment combinations but were found at par with each other. These were followed by W_2S_{40}, W_3S_{60} and W_4S_{40} combinations in increasing the haulm yield of the crop.

Biological yield:-Weed control:- Biological yield of crop followed the same trend that was noted in pod and haulm yields with different weed control treatments (Table 4.8). Pre emergence application of pendimethalin at 0.75 kg/ha provided biological yield of 5310 kg/ha that was statistically similar with weed free treatment (5643 kg/ha). It increased the haulm yield quantitatively by 891, 1373 and 2545 kg/ha over imazethapyr at 100 g/ha, fluazifop-p-butyl at 0.20 kg/ha and control, respectively. It was closely accompanied by one HW at 25 DAS (5009 kg/ha) which also witnessed 13.3, 27.3 and 81.1 per cent increase over the above mentioned treatments. Imazethapyr 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha also improved the biological yield by magnitude of 59.9 and 42.2 per cent over weedy check treatment and proved the next better and equally effective treatments.

Sulphur levels:-Biological yield of groundnut was also improved to a considerable extent due to application of graded level of sulphur (Table 4.8). Application of sulphur at 60 kg/ha provided the highest biological yield of (5678 kg/ha) that was higher by 414, 1331 and 2915 kg/ha in comparison to 40 and 20 kg S/ha and control, respectively.

Interaction:-It was observed from the data (Table 4.8.1) that application of pendimethalin at 0.75 kg/ha combined with 60 kg S/ha (W_4S_{60}) produced the biological yield of 7099 kg/ha that was as good as obtained from weed free plots fertilized with 60 kg S/ha (W_2S_{60}). It was closely followed by W_2S_{40}, W_3S_{60} and W_4S_{40} combinations which corresponded to biological yields of 6582, 6302 and 6193 kg/ha, respectively.

Harvest index:-Weed control: It is clear from the data presented in table 4.8 that different weed control treatments could not bring variation in harvest indices up to the level of significance.

Sulphur levels:-Results further indicated that all the levels of S fertilization significantly enhanced the harvest index of crop in comparison to control (Table 4.8). However, they remained at par among themselves. The maximum harvest index of 35.85 per cent was recorded at 20 kg S/ha that was followed by 60 and 40 kg S/ha.

Shelling percentage:-Weed control:**-** A critical examination of the data (Table 4.8) indicated that all the treatments except fluazifop-p-butyl at 0.20 kg/ha represented significantly higher shelling percentage than weedy check. However, they remained at par among themselves. Weed free and pendimethalin at 0.75 kg/ha were found to be the most superior treatments in this regard. These treatments significantly increased the shelling percentage by margin of 5.72 and 4.28 per cent over fluazifop-p-butyl at 0.20 kg/ha and 8.57 and 6.55 per cent over weedy check treatments, respectively. One HW at 25 DAS and imazethapyr at 100 g/ha also enhanced the shelling percentage by magnitude of 6.55 and 4.87 per cent over weedy check treatment and thus emerged as the next better and equally effective treatments.

Sulphur levels:- Data (Table 4.8) further revealed that every increase in level of sulphur upto 60 kg/ha significantly increased the shelling percentage in groundnut over preceding levels. The increase in shelling due to 60 kg S/ha was 2.41, 5.81 and 8.79 per cent over 40 kg and 20 kg S/ha and control, respectively.

Table 4.8 Effect of weed control and sulphur levels on yield, harvest index and shelling percentage

Treatments	Yield (kg/ha)					Shelling percentage
	Pod yield	Haulm yield	Biological yield	Harvest index (%)	Kernel yield (kg/ha)	
Weedy check	977	1788	2765	35.13	635	64.23
Weed free	1971	3671	5643	34.73	1453	72.80
One HW at 25 DAS	1750	3259	5009	34.73	1254	70.78
Pendimethalin @ 0.75 kg/ha	1854	3456	5310	34.71	1339	71.36
Fluazifop-p-butyl @ 0.20 kg/ha	1343	2590	3933	33.93	912	67.08
Imazethapyr @ 100 g/ha	1555	2864	4419	34.99	1088	69.10
SEm±	48.07	73	130	0.81	38	1.51
CD (P = 0.05)	151.47	230	410	NS	119	4.77
CV (%)	10.57	9.0	10.0	8.12	12	7.57
Sulphur levels (kg/ha)						
0	908	1855	2763	32.87	592	64.61
20	1558	2789	4347	35.85	1067	67.89
40	1835	3429	5264	34.87	1314	70.99
60	1999	3679	5678	35.22	1480	73.40
SEm±	26.29	54	78	0.58	27	0.86
CD (P = 0.05)	69.81	144	207	NS	71	2.27
Interaction (WxS)	Sig.	Sig.	Sig.	NS	NS	NS
CV (%)	7.08	8.0	7.0	7.14	10	5.25

NS= Non significant Sig.= Significant

Kernels yield:-Weed control:- Like pod and haulm, kernel yield of groundnut was also significantly enhanced due to different weed control treatments (Table 4.8). Weed free and pendimethalin at 0.75 kg/ha produced the respective kernels yields of 1453 and 1339 kg/ha and found equally effective. These treatments increased the kernel yield by 33.6 and 23.0 per cent over imazethapyr at 100 g/ha, 59.3 and 46.9 per cent over fluazifop-p-butyl 0.20 kg/ha and 125.2 and 110.9 per cent over weedy check treatments, respectively. One HW at 25 DAS also increased the kernel yield to the extent of 15.2, 37.5 and 97.5 per cent over imazethapyr at 100 g/ha, fluazifop-p-butyl at 0.20kg/ha and weedy check, respectively and showed statistical equivalence with pendimethalin at 0.75 kg/ha.

Sulphur levels:-Results revealed that groundnut responded favourably to sulphur fertilization (Table 4.8). Application of S at 60 kg/ha provided the kernel yield of 1480 kg/ha that was 12.7, 38.8 and 150 per cent more than obtained under 40 and 20 kg S/ha and control, respectively.

Interaction: it was noted in the results (Table 4.8.2) that combined effect of weed control treatments and sulphur fertilization indicated that weed free integrated with 60 kg S/ha (W_2S_{60}) produced the kernel yield of 1932 kg/ha that was found at par with that obtained when pendimethalin at 0.75 kg/ha was combined with 60 kg S/ha (W_4S_{60}). W_2S_{40}, W_3S_{60} and W_4S_{40} were the next better performing and equally effective treatment combinations in regard of increasing kernel yield.

Table- 4.8.2 Combined effect of weed control and sulphur levels on kernels yield (kg/ha)

Treatments	S_0	S_{20}	S_{40}	S_{60}
W_1 - Weedy check	338	609	750	844
W_2 - Weed free	772	1392	1715	1932
W_3 - One HW at 25 DAS	666	1202	1480	1667
W_4 - Pendimethalin @ 0.75 kg/ha (PE)	712	1283	1581	1780
W_5 - Fluazifop-p-butyl @ 0.20 kg/ha (POE)	485	874	1076	1212
W_6 - Imazethapyr @ 100 g/ha (PE)	578	1043	1284	1446
For S at same level of W				
SEm±				65.77
CD (P=0.05)				188.63
For W at same or different levels of S				
SEm±				48.27
CD (P=0.05)				137.30

Weed competition index:-Weed control: It is obvious from the data presented in table 4.9 that different weed control treatments differed widely in their effect on weed competition indices. The maximum crop-weed competition due to unrestricted growth of weeds in weedy check plots resulted the highest reduction of 50.43 per cent in pod yield of groundnut than weed free treatment. On the other hand, the least reduction in pod yield due to presence of weeds was observed in pre-emergence application of pendimethalin at 0.75 kg/ha treated plots (8.26%) that was closely accompanied by one HW at 25 DAS treatment (11.21%). Application of imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha were found to be the next superior treatments in reducing crop weed- competition that was reflected in lower weed competition indices of 21.10 and 31.86 per cent under these treatments.

Table 4.9 -Effect of different weed control treatment on weed competition index

Treatment	Weed competition index (%)
Weedy check	50.43
Weed free	-
One HW at 25 DAS	11.21
Pendimethalin @ 0.75 kg/ha	8.26
Fluazifop-p-butyl @ 0.20 kg/ha	31.86
Imazethapyr @ 100 g/ha	21.10

Nutrient concentration, uptake and quality parameters:- Nitrogen concentration in weeds:-Weed control: -A perusal of data presented in table 4.10 revealed that all the weed control treatments except fluazifop-p-butyl at 0.20 kg/ha recorded significantly higher N concentration in weed dry matter than weedy check treatment. Remaining at par with each other, pendimethalin at 0.75 kg/ha and one HW at 25 DAS treatments recorded significantly higher N concentration of 1.88 and 1.86% in weed dry matter at harvest stage. Imazethapyr at 100 g/ha also registered significantly higher N concentration in weeds (1.82%) and thus found at par with above described treatments.

Sulphur levels: It is also clear from the data (Table 4.10) that application of sulphur at 40 kg/ha, being at par with 20 kg S/ha significantly increased the N concentration in weeds than control (1.70%). Further increase in its level to 60 kg/ha did not bring significant variation in N concentration.

Phosphorus concentration in weeds:-Weed control:- Phosphorus concentration in weeds was also significantly influenced due to one HW at 25 DAS and pendimethalin at 0.75 kg/ha treatments (Table 4.10). Remaining at par with weed free, these treatments registered P concentration of 0.283 and 0.281%, respectively. Rest of the treatments recorded statistically similar P concentration in weeds when compared with weedy check treatment.

Sulphur levels:-Results further showed that application of sulphur at 60 kg/ha recorded significantly higher P concentration in weeds (0.284%) than 20 kg S/ha and control. However, it was found at par with 40 kg S/ha (Table 4.10).

Potassium concentration in weeds:-Weed control:- It is apparent from the data (Table 4.10) that all the weed control treatments attained significantly higher K concentration in weed dry matter at harvest stage of crop than weedy check. Pendimethalin at 0.75 kg/ha, one HW at 25 DAS, imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha recorded 15.4, 14.0, 13.3 and 11.9 per cent higher K concentration in weeds than unweeded control, respectively. However, they remained at par among themselves.

Sulphur levels:-It is also clear from the data (Table 4.10) that sulphur fertilization at 20 kg/ha resulted a significant increase of 6.0 per cent over control. Further increase in its level to 40 and 60 kg S/ha did not bring significant variation in K concentration over 20 kg S/ha.

Table 4.10-Effect of weed control and sulphur levels on nutrient concentration in weeds at harvest of the crop

Treatments	Nutrient concentration in weeds (%)		
	N	P	K
Weed control			
Weedy check	1.66	0.258	1.43
Weed free	0.0	0.000	0.00
One HW at 25 DAS	1.86	0.283	1.63
Pendimethalin @ 0.75 kg/ha	1.88	0.281	1.65
Fluazifop-p-butyl @ 0.20 kg/ha	1.78	0.262	1.60
Imazethapyr @ 100 g/ha	1.82	0.276	1.62
SEm±	0.04	0.006	0.04
CD (P = 0.05)	0.14	0.019	0.15
CV (%)	8.23	7.271	9.71
Sulphur levels (kg/ha)			
0	1.70	0.257	1.50
20	1.78	0.269	1.59
40	1.83	0.277	1.62
60	1.89	0.284	1.64
SEm±	0.03	0.005	0.03
CD (P = 0.05)	0.07	0.012	0.08
CV (%)	6.45	7.05	7.86

Nitrogen depletion by weeds:-Weed control: - A reference to data presented in table 4.11 and fig. 4.7 revealed that all the weed control treatments results significantly lower depletion of N by weeds in comparison to weedy check at harvest stage of the crop. Keeping the field weed free throughout the growing season results no depletion of N under this treatment. Remaining at par with one HW at 25 DAS, pendimethalin at 0.75 kg/ha (PE) recorded the lowest depletion of 8.63 kg N/ha, thereby reducing it quantitatively by 4.19, 7.31 and 36.8 kg/ha over imazethapyr at 100 g/ha, fluazifop-p-butyl at 0.20 kg/ha and weedy check treatments, respectively. The corresponding reduction due to one HW at 25 DAS was 2.62, 5.74 and 35.24 kg/ha. Pre emergence application of imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha at 25 DAS also registered 71.8 and 65.0 per cent decline in N depletion than weedy check and thus proved the next better treatment in this regard.

Sulphur levels:-It is further apparent from the data that increasing levels of S fertilization in groundnut also caused significantly higher N depletion by weeds upto its highest level of 60 kg/ha (Table 4.11 and Fig. 4.7). This level of S resulted in the maximum depletion of 20.98 kg N/ha that was 5.5, 1.30 and 39.9 per cent more than recorded under 40 and 20 kg S/ha and control, respectively.

Interaction:- Depletion of N by weeds at harvest stage of the crop was also significantly influenced due to interactive effect of weed control and S fertilization. Data presented in table 4.11.1 indicated that weedy check treatment observed significantly higher N depletion by weed up to highest level of 60 kg S/ha. The remaining weed control treatments performed superior in reducing N depletion at subsequent N level. The lowest depletion of 6.96 kg N/ha was obtained with pendimethalin at 0.75 kg/ha along with no S fertilization (W_4S_0) which reduced the N depletion by a huge margin of 44.29 kg/ha than $W_1S_{60,}$ wherein the maximum depletion of 51.25 kg N/ha was noted. However, it was found at par with W_3S_0 and W_4S_0 treatment combinations that also witnessed N depletion values of just 8.22 and 8.61 kg/ha, only.

Phosphorus depletion by weeds:-Weed control:- A comparison of weed control treatments (Table 4.11 and Fig. 4.7) revealed that all the treatments significantly reduced the P depletion of weeds in comparison to weedy check treatment at harvest stage of the crop. Remaining at par with each other, pendimethalin at 0.75 kg/ha and one HW at 25 DAS treatments reduced the P depletion by huge a margin of 81.8 and 78.0 per cent, respectively than recorded under weedy check treatment. These treatments also showed their superiority over imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha which recorded 72.6 and 66.9 per cent lower P depletion than weedy check, respectively. Unrestricted growth of weeds under weedy check plots resulted in the maximum depletion of 7.06 kg P_2O_5/ha due to weeds.

Sulphur levels:-Every addition in level of sulphur upto its highest level of 60 kg/ha also brought about significantly higher P depletion by weeds (Table 4.11 and Fig. 4.7). The maximum P depletion of 3.18 kg/ha was found under 60 kg S/ha that was 4.7, 12.3 and 38.9 per cent higher than obtained under 40 and 20 kg S/ha and control, respectively.

Interaction:- Interactive effect of weed control and S fertilization also influenced the P depletion by weeds in the same manner as observed under N depletion (Table 4.11.1). Weedy check treatment recorded significantly higher P depletion by weeds when combined with all levels of sulphur. Unfertilized plots of pendimethalin at 0.75 kg/ha and one HW at 25 DAS (W_4S_0 and W_3S_0) and pendimethalin at 0.75 kg/ha combined with 20 kg S/ha (W_4S_{20}) attained significantly lower P depletion of 1.04, 1.25 and 1.29 kg/ha, respectively than most of the treatment combinations. However, they were found at par among themselves. $W_4S_{40,}$ W_4S_{60} and W_2S_{40} were noted to the next better and equally effective treatment combinations in reducing P depletion by weeds.

Table 4.11 Effect of Weed control and sulphur levels on nutrient depletion by weeds at harvest stage of the crop

Treatments	**Nutrient depletion (kg/ha)**		
	N	**P**	**K**
Weed control			
Weedy check	45.44	7.06	39.26
Weed free	0.00	0.00	0.00
One HW at 25 DAS	10.20	1.55	8.95
Pendimethalin @ 0.75 kg/ha	8.63	1.29	7.58
Fluazifop-p-butyl @ 0.20 kg/ha	15.94	2.34	14.28
Imazethapyr @ 100 g/ha	12.82	1.94	11.43
SEm±	0.56	0.11	0.43
CD (P = 0.05)	1.82	0.35	1.40
CV (%)	10.38	13.08	9.11
Sulphur levels (kg/ha)			
0	15.00	2.29	13.15
20	18.56	2.83	16.47
40	19.89	3.04	17.50
60	20.98	3.18	18.09
SEm±	0.28	0.05	0.27
CD (P = 0.05)	0.74	0.13	0.73
Interaction (WxS)	Sig.	Sig.	Sig.
CV (%)	6.30	7.27	7.14

Sig. = Significant

Potassium depletion by weeds:-Weed control:- Potassium depletion by weeds at harvest stage was influenced by different weed control treatment in the same manner as N and P depletion (Table 4.11 and Fig. 4.7). Pre emergence application of pendimethalin at 0.75 kg/ha resulted in the significantly lowest depletion of 7.42 kg/ha, only by weeds. In this way, it withnessed 33.7, 46.9 and 80.7 per cent lower depletion than imazethapyr at 100 g/ha, fluazifop-p-butyl at 0.20 kg/ha and weedy check treatments, respectively. However, it was found at par with one HW at 25 DAS which corresponded to 21.7, 37.3 and 77.2 per cent reduction in K depletion. Imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha were found the next superior treatments which reduced the K depletion by magnitude of 27.83 and 24.98 kg/ha as compared to weedy check.

Sulphur levels:- Like N and P, K depletion by weeds at harvest also increased significantly with successive increase in graded levels of sulphur upto 60 kg/ha (Table 4.11 and Fig. 4.7) that was 3.3, 10.0 and 37.6 per cent more than obtained under 40 and 20 kg S/ha and control, respectively.

Interaction:-It was noted from the results presented in table 4.11.1 that different weed control treatments differed widely in K depletion by weeds when combined with different levels of S. Lower K depletion values were obtained under most of the weed control treatments when they were not fertilized with sulphur. However, weedy check treatment responded positively upto 40 kg S/ha. W_4S_0, W_3S_0 and W_4S_{20} were among the most superior treatment combinations in regard of reducing K depletion by weeds. Remaining at par among themselves, these treatment combinations reduced the K depletion by margin of 37.55, 36.35 and 35.91 kg/ha than W_1S_{60}, wherein the maximum depletion of 65.09 K/ha was obtained.

Nitrogen concentration in crop:-Weed control:- A critical examination of the data presented in table 4.12 revealed that all the weed control treatments significantly enhanced the N concentration in kernel and haulm of groundnut. The maximum concentration of 3.89 and 2.10 per cent in kernel and haulm was noted under weed free treatment that was followed by one HW at 25 DAS (3.84 and 2.07%), pendimethalin at 0.75 kg/ha (3.78 and 2.07%) and imazethapyr at 100 g/ha (3.69 and 2.06%). However, the difference in N concentration among these four treatments was not upto the level of significance. Application of fluazifop-p-butyl at 0.20 kg/ha at 25 DAS also recorded 11.3 and 19.7 per cent higher N concentration in kernels and haulm, respectively and found significantly superior than unwedded control.

Sulphur level: Sulphur fertilization in crop also recorded significant increase in N concentration in kernel and haulm (Table 4.12). Application of sulphur at 40 kg/ha improved the N concentration by 5.1 and 13.8 per cent in kernel and 9.8 and 32.3 per cent in haulm over 20 kg S/ha and control, respectively. Further increase in its level to 60 kg/ha, though, maximized its concentration in kernel and haulm (3.76 and 2.21%), yet the increase was not up to the level of significance.

Phosphorus concentration in crop:-Weed control:- All the weed control treatments except fluazifop-p-butyl at 0.20 kg/ha, brought about significantly higher values of P concentration in kernel and haulm of groundnut than weedy check (Table 4.13). The maximum concentration in kernel (0.888%) was obtained under weed free treatment and was accompanied by pendimethalin at 0.75 kg/ha, one HW at 25 DAS and imazethapyr at 100 g/ha. Remaining at par among them, these treatments enhanced the P concentration in kernel to the extent of 18.6, 18.3, 15.4 and 9.7 per cent, respectively over weedy check treatment. The corresponding increase in haulm was 25.3, 24.9, 22.4 and 15.7 per cent.

Sulphur levels:-increasing the level of S from 0 to 20 kg/ha significantly improved the P concentration in kernel and whereas in haulm, it was recorded up to 40 kg S/ha (Table 4.13). Sulphur fertilization at 40 kg/ha increased the P concentration in kernel and haulm to the tune of 14.4 and 33.4 per cent over unfertilized control, respectively. However, it was found at par with 60 kg S/ha wherein the maximum P concentration in kernel and haulm were recorded.

Table 4.12 Effect of weed control and sulphur levels on N concentration and its total uptake

Treatments	N concentration (%)		Total N uptake (kg/ha)
	Kernel	Haulm	
Weed control			
Weedy check	3.34	1.57	48.12
Weed free	3.76	2.14	137.92
One HW at 25 DAS	3.84	2.10	119.05
Pendimethalin @ 0.75 kg/ha	3.78	2.07	124.72
Fluazifop-p-butyl @ 0.20 kg/ha	3.00	1.88	80.86
Imazethapyr @ 100 g/ha	3.69	2.06	101.24
SEm±	0.09	0.04	4.35
CD (P = 0.05)	0.28	0.14	13.70
CV (%)	8.68	7.66	14.77
Sulphur levels (kg/ha)			
0	3.26	1.61	50.17
20	3.53	1.94	93.67
40	3.71	2.13	124.31
60	3.76	2.21	139.79
SEm±	0.06	0.03	2.26
CD (P = 0.05)	0.16	0.09	6.01
interaction (WxS)	NS	NS	Sig.
CV (%)	7.34	7.38	9.41

NS= Non significant Sig. = Significant

Table 4.13 Effect of weed control and sulphur levels on P concentration and its total uptake

Treatments	P concentration (%)		Total P uptake (kg/ha)
	Karnel	Haulm	
Weed control			
Weedy check	0.749	0.434	12.82
Weed free	0.888	0.544	33.67
One HW at 25 DAS	0.864	0.531	28.81
Pendimethalin @ 0.75 kg/ha	0.886	0.542	31.34
Fluazifop-p-butyl @ 0.20 kg/ha	0.765	0.492	20.21
Imazethapyr @ 100 g/ha	0.822	0.502	23.90
SEm±	0.020	0.012	0.89
CD (P = 0.05)	0.064	0.038	2.81
CV (%)	8.49	8.20	10.66
Sulphur levels (kg/ha)			
0	0.743	0.407	12.14
20	0.826	0.515	23.55
40	0.864	0.543	30.45
60	0.883	0.564	34.36
SEm±	0.013	0.009	0.74
CD (P = 0.05)	0.036	0.024	1.96
Interaction (WxS)	NS	NS	Sig.
CV (%)	6.88	7.45	10.79

NS= Non significant Sig. = Significant

Sulphur concentration in crop:-Weed control:**-** It is obvious from the data that weed control treatments differed widely in influencing the S concentration in crop (Table 4.14). Weed free, pendimethalin at 0.75 kg/ha and HW at 25 DAS recorded 0.227, 0.221 and 0.206 per cent S concentration in kernel and thus found the most superior treatments by increasing it to the extent of 40.1, 36.4 and 27.2 per cent than weedy check treatment, respectively. These treatments also represented significantly higher S concentration of 0.185, 0.181 and 0.173 per cent in haulm of the crop. Imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha also witnessed 19.8 and 13.0 per cent higher S concentration in kernel and 23.3 and 14.0 per cent in haulm than weedy check and proved equally effective in this regard.

Sulphur levels:- It is further evident from the data presented in table 4.14 that progressive increase in level of S up to 40 kg/ha significantly enhanced the S concentration in kernel by 18.5 and 31.3 per cent and in haulm by 9.4 and 29.9 per cent, over 20 kg S/ha and control, respectively. Further increase in its level to 60 kg/ha, though, maximized the concentration but the difference was not up to the level of significance.

Table 4.14 Effect of weed control and sulphur levels on S concentration and its total uptake by crop

Treatments	S concentration (%)		*Total S uptake (kg/ha)*
	Karnel	Haulm	
Weed control			
Weedy check	0.162	0.129	5.22
Weed free	0.227	0.185	15.15
One HW at 25 DAS	0.206	0.173	12.67
Pendimethalin @ 0.75 kg/ha	0.221	0.181	13.93
Fluazifop-p-butyl @ 0.20 kg/ha	0.183	0.147	8.55
Imazethapyr @ 100 g/ha	0.194	0.159	10.33
SEm±	0.01	0.006	0.45
CD (P = 0.05)	0.02	0.018	1.43
CV (%)	9.91	11.99	11.76
Sulphur levels (kg/ha)			
0	0.166	0.134	5.00
20	0.185	0.159	10.14
40	0.218	0.174	13.39
60	0.226	0.182	15.37
SEm±	0.003	0.004	0.29
CD (P = 0.05)	0.009	0.010	0.76
Interaction (WxS)	NS	NS	Sig.
CV (%)	7.06	9.39	9.10

NS= Non significant, Sig. = Significant

Nitrogen uptake by crop:-Weed control:- Total uptake of N by crop was found to be significantly improved due to all the weed control treatments (Table 4.12 and Fig. 4.8). The highest uptake of 132.92 kg/ha was obtained under weed free treatment. Pendimethalin at 0.75 kg/ha and one HW at 25 DAS were noted to be the next superior and equally effective treatments. Witnessing N uptake of 124.72 and 119.05 kg/ha, these treatments significantly enhanced the N uptake by margin of 23.48 and 17.81 kg/ha on imazethapyr at 100 g/ha, 43.86 and 38.19 kg/ha on fluazifop-p-butyl at 0.20 kg/ha and 76.6 and 70.93 kg/ha over weedy check treatments, respectively. Imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha were the next better treatments which also registered 110.3 and 68.0 per cent higher uptake of N by crop than recorded under weedy check.

Sulphur levels:- It is also evident from the data presented in table 4.12 and fig. 4.8 that progressively increasing levels of S results significant enhancement in N uptake by crop over preceding levels. The highest uptake of 139.79 kg/ha was recorded with 60 kg S/ha that was 12.5, 49.2 and 178.7 per cent higher than obtained under 40 and 20 kg S/ha and control, respectively.

Interaction:-N uptake in crop was also influenced due to combined effect of weed control and sulphur levels (Table 4.14.1). Results showed that integration of 60 kg S/ha either with weed free (W_2S_{60}) or with pendimethalin at 0.75 kg/ha (W_4S_{60}) recorded 189.07 and 170.97 kg uptake of N/ha that was significantly higher than most of the treatment combinations except W_2S_{40} and W_3S_{60}. These two treatment combinations thus increased the N uptake by magnitude of 165.39 and 147.29 kg/ha over unfertilized weedy check plots (W_1S_0) wherein, the minimum uptake of 23.68 kg N/ha was recorded.

Phosphorus uptake by crop:-Weed control:- It can be inferred from the data (Table 4.13 and Fig. 4.8) that all the measures evaluated for weed control in groundnut recorded substantially higher uptake of P by crop than weedy check. Though, the highest uptake of 33.67 kg P/ha was observed under weed free treatment but it showed statistical similarity with pendimethalin at 0.75 kg/ha which also recorded considerably higher uptake of 30.59 kg/ha. These two treatments thus resulted the quantum increase of 9.77 and 7.44 kg/ha over imazethapyr at 100 g/ha; 13.46 and 11.03 kg/ha over fluazifop-p-butyl at 0.20 kg/ha and 20.85 and 18.52 kg/ha over weedy check treatments, respectively. Being at par with pendimethalin at 0.75 kg/ha, one HW at 25 DAS also recorded significantly higher uptake of 28.81 kg P/ha. These were followed by imazethapyr at 100g/ha and fluazifop-p-butyl at 0.20 kg/ha treatments that also registered 86.5 and 57.6 per cent more P uptake than weedy check.

Sulphur levels:-Sulphur fertilization also significantly increased the P uptake by crop (Table 4.13 and Fig. 4.8). Application of S at 60 kg/ha provided the highest P uptake of 34.36 kg/ha and thus observed 12.8, 45.9 and 183.0 per cent increase over 40, 20 and 0 kg S/ha, respectively.

Interaction:-Interactive effect of different weed control treatments and levels of sulphur was also significantly influence the P uptake by crop (Table 4.14.1). Response to higher levels of S was more apparent under most of the weed control treatments than weedy check. Weed free treatment integrated with 60 kg S/ha (W_2S_{60}) and application of pendimethalin at 0.75 kg/ha in conjunction with 60 kg S/ha (W_4S_{60}) were the most superior treatment combinations which attained uptake of 46.06 and 42.86 kg/ha. Being at par with each other, these combinations registered quantitative increase of 39.87 and 36.67 kg/ha over unfertilized weedy check (W_1S_0) which recorded P uptake of just 6.19 kg P/ha, only. W_2S_{40}, W_3S_{60} and W_4S_{40} were the next better and equally effective treatment combinations in enhancing P uptake by crop.

Sulphur uptake by crop:-Weed control:- Perusal of data presented in table 4.14 and fig. 4.8 revealed that total uptake of S by crop was influenced by different weed management treatments in the same manner as N and P uptake. The maximum uptake of 10.08 kg/ha was obtained under weed free treatment. It was followed by pendimethalin at 0.75 kg/ha and one HW at 25 DAS treatments. Remaining at par with each other, these treatments also led significant enhancement in S uptake to the tune of 166.9 and 142.7 per cent over weedy check. Imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha were noted to be the next superior treatments by registering 10.33 and 8.55 kg uptake of S/ha which was 97.9 and 63.8 per cent more than unweeded control, respectively.

Sulphur levels:-It is evident from the data presented in table 4.14 and fig. 4.8 that every increase in level of sulphur resulted significant enhancement in S uptake by crop upto its highest level of 60 kg/ha over lower levels. It witnessed S uptake of 15.37 kg/ha that was more by 1.98, 5.23 and 10.37 kg/ha than obtained under 40, 20 and 0 kg S/ha, respectively.

Interaction:-Like N and P, S uptake was also affected due to combined effect of weed control treatments and sulphur levels (Table 4.14.1). Data showed that positive response of higher levels of S fertilization in terms of total S uptake was more reflected in treatments witnessing higher weed control efficiencies. Integration of S levels with weed free, pendimethalin and fluazifop-p-butyl treatments significantly improved the S uptake upto highest level of 60 kg S/ha. Weed free fertilized with 60 kg S/ha (W_2S_{60}) and pendimethalin at 0.75 kg/ha alongwith 60 kg S/ha (W_4S_{60}) recorded statistically equivalent S uptake values of 21.21 and 19.50 kg/ha which were higher by magnitude of 18.83 and 17.12 kg/ha over unfertilized weedy check (W_1S_0), wherein, minimum uptake of sulphur was obtained. W_2S_{40}, W_3S_{60} and W_4S_{40} were the next better and statistically similar treatment combinations in regard of enhancing S uptake by crop.

Protein content in kernel:-Weed control:- Like N, protein content in kernel was also influenced significantly due to different weed control treatments (Table 4.15). The highest protein content of 24.74 per cent was obtained with weed free treatment. One HW at 25 DAS (23.83%), pendimethalin at 0.75 kg/ha (23.46%) and imazethapyr at 100 g/ha (22.90%) were next in order and equally effective treatments with weed free in this quality character. Fluazifop-p-butyl at 0.20 kg/ha also improved the protein content to the extent of 11.3 per cent and found significantly better than weedy check.

Sulphur levels:- Results further showed that every increase in graded levels of sulphur upto 40 kg/ha brought about significantly higher protein content over lower levels (Table 4.15). It recorded protein content of 23.19 per cent that was 5.1 and 13.8 per cent more than 20 kg S/ha and control, respectively. Further addition in S level to 60 kg/ha did not bring significant improvement in protein content in kernel.

Oil content in kernels:-Weed control:- It can be inferred from the data presented in table 4.15 that oil content in kernel was significantly improved due to all the weed control treatments except fluazifop-p-butyl at 0.20 kg/ha in comparison to weedy check. The highest oil content of 43.87 was recorded by weed free that was closely accompanied by application of pendimethalin at 0.75 kg/ha (43.85%), one HW at 25 DAS (42.86%) and imazethapyr at 100 g/ha (42.02%). Remaining at par among them, these four treatments rendered significant enhancement of 15.3, 15.2, 12.7 and 10.4 per cent in oil content over weedy check treatment, respectively. Fluazifop-p-butyl did not significantly enhance the oil content than weedy check, however, it was found at par with rest of the treatments except weed free.

Sulphur levels:-It is also clear from the data that S fertilization in groundnut significantly improved the oil content by crop (Table 4.15). The highest oil content of 45.64% was obtained with the application of S at 60 kg/ha which was 5.0, 10.6 and 22.7 per cent more as compared to 40, 20 and 0 kg S/ha, respectively.

Oil yield:-Weed control:- Perusal of data showed that all the weed control treatment significantly augmented the oil yield over weedy check (Table 4.15). The highest oil yield of 652.9 kg/ha was obtained under weed free treatment that was very closely followed by pendimethalin at 0.75 kg/ha (600.3 kg/ha). Remaining at par with each other, these two treatments increased the oil yield by margin of 186.0 and 133.41 kg/ha over imazethapyr at 100 g/ha; 273.68 and 221.16 kg/ha over fluazifop-p-butyl at 0.20 kg/ha; and 405.89 and 353.37 kg/ha over weedy check treatments, respectively. Providing the oil yield 549.0 kg/ha, one HW at 25 DAS also showed statistical equivalence with pendimethalin at 100 g/ha. Imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha were noted to be the next better treatments that registered 89.0 and 53.6 per cent higher oil yield than weedy check, respectively.

Sulphur level:- Results further indicated that increasing levels of sulphur resulted in significantly higher oil yield over preceding levels (Table 4.15). Application of sulphur at 60 kg/ha provided the oil yield of 684.5 kg/ha and thus increased it to the extent of 15.7, 53.7 and 207.6 per cent than under 40, 20 and 0 kg S/ha, respectively.

Interaction:-Interactive effect of weed control treatments and sulphur fertilization was also found to significantly affect the oil yield of groundnut (Table 4.15.1). Weed free integrated with 60 kg S/ha (W_2S_{60}) gave the highest oil yield of 938.8 kg/ha that was found at par with pendimethalin at 0.75 kg/ha combined with 60 kg S/ha (W_4S_{60}) that also witnessed oil yield of 852.7 kg/ha. Providing the oil yields of 775.1 774.2 and 658.8 kg/ha, W_2S_{40}, W_3S_{60} and W_4S_{40} were found the next superior and equally effective treatment combinations.

Table 4.15-Effect of weed control and sulphur levels on protein, oil content in kernel and oil yield

Treatments	Protein content (%)	Oil content (%)	Oil yield (kg/ha)
Weed control			
Weedy check	18.62	38.06	247.0
Weed free	24.14	43.87	652.9
One HW at 25 DAS	23.83	42.86	549.0
Pendimethalin @ 0.75 kg/ha	23.46	43.85	600.3
Fluazifop-p-butyl @ 0.20 kg/ha	20.73	40.71	379.2
Imazethapyr @ 100 g/ha	22.90	42.02	466.9
SEm±	0.67	1.02	17.34
CD (P = 0.05)	2.10	3.21	54.65
CV (%)	10.34	8.41	12.45
Sulphur levels (kg/ha)			
0	20.38	37.21	222.7
20	22.06	41.30	445.7
40	23.19	43.43	577.2
60	23.50	45.64	684.5
SEm±	0.53	0.66	13.39
CD (P = 0.05)	1.40	1.76	35.55
Interaction (WxS)	NS	NS	Sig.
CV (%)	10.02	6.72	11.77

NS = Non significant Sig. = Significant

Table 4.15.1-Combined effect of weed control and sulphur levels on oil yield (kg/ha)

Treatments	S_0	S_{20}	S_{40}	S_{60}
W_1 - Weedy check	114.4	228.8	296.4	348.3
W_2 - Weed free	299.1	598.5	775.1	938.8
W_3 - One HW at 25 DAS	254.2	508.7	658.8	774.2
W_4 - Pendimethalin @ 0.75 kg/ha	276.9	554.1	717.6	852.7
W_5 - Fluazifop-p-butyl @ 0.20 kg/ha	175.6	351.4	455.0	534.7
W_6 - Imazethapyr @ 100 g/ha	216.2	432.7	560.3	658.5
For S at same level of W				
SEm±				32.8
CD (P=0.05)				94.1
For W at same or different levels of S				
SEm±				23.5
CD (P=0.05)				66.9

Sulhpur use efficiency:- Weed control:- Data pertaining to the effect of various levels of phosphorus on sulphur use efficiencies revealed that successive increase in the level of phosphorus increased the agronomic efficiency and apparent recovery of S (Table 4.12). Application of phosphorus at 60 kg/ha registered the highest agronomic efficiency of 7.01 kg grain/kg S. It also represented the maximum apparent recovery of 8.49% S. However, the highest physiological efficiency of 98.60 kg grain/kg S was obtained when phosphorus was applied at 20 kg/ha. Thereafter, it decreased slightly.

Sulphur:-Data (Table 4.12) further indicated that sulphur use efficiencies were influenced in inverse manner due to sulphur fertilization. Application of sulphur at 15 kg/ha recorded the maximum agronomic efficiency (7.93 kg grain/kg S) and apparent recovery of S (8.97%) which showed declining trend with increase in sulphur level. The minimum values of these two efficiencies were noted at 45 kg S/ha. On the other hand, physiological efficiency of S registered its highest value (91.03 kg grain/kg S) when sulphur level was increased from 15 to 30 kg/ha. But, further increase in its level to 45 kg/ha, again declined the physiological efficiency to 82.73 kg grain/kg S.

Table 4.16-Effect of weed control and phosphorus levels on phosphorus use efficiencies

Treatments	AEs (kg grain/kg S)	REs (%)	PEs (kg grain/kg S uptake)
A. Weed control			
W_1 - Weedy check	11.45	8.85	147.59
W_2 - Weed free	23.11	24.72	191.77
W_3 - One HW at 25 DAS	20.52	19.87	174.79
W_4 - Pendimethalin @ 0.75 kg/ha (PE)	21.73	17.74	188.32
W_5 - Fluazifop-p-butyl @ 0.20 kg/ha (POE)	15.74	12.74	184.56
W_6 - Imazethapyr @ 100 g/ha (PE)	18.23	15.22	164.55
B. Sulphur levels (kg/ha)			
0	-	-	-
20	32.50	27.86	474.61
40	23.18	20.96	116.42
60	18.18	17.28	110.02

AEs = Agronomic efficiency of S (kg grain/kg S), REs = Apparent recovery of S (%), PEs = Physiological efficiency of S (kg grain/kg uptake of S)

Economics of treatments:-Net returns:-Weed control:- It is obvious from the data presented in table 4.16 and fig. 4.9 that net returns in groundnut were significantly increased due to all the weed control treatments. Result showed that weed free and pendimethalin at 0.75 kg/ha were the most superior and equally effective treatments in obtaining net returns. Fetching the net returns of ` 63546 and 62319/ha, these treatments provided additional net returns of ` 15400 and 14173/ha than imazethapyr at 100 g/ha, ` 25813 and 24586/ha than fluazifop-p-butyl at 0.20 kg/ha and ` 42591 and 41364/ha than weedy check treatments, respectively. Being at par with pendimethalin at 0.75 kg/ha, one HW at 25 DAS also registered a corresponding increase of 17.9, 50.5 and 170.9 per cent in net returns than above mentioned treatments. Providing the net returns of ` 49470 and 39057/ha, application of imazethapyr at 100 g/ha (PE) and fluazifop-p-butyl at 0.20 kg/ha at 25 DAS were noted to be the next better treatments. The extent of increase in net returns rendered by these two treatments was 129.8 and 80.0 per cent, respectively in comparison to weedy check treatment.

Sulphur levels:-It is further evident from the data (Table 4.16 and Fig. 4.9) that increasing levels of sulphur fetched significantly higher net returns upto its highest level of 60 kg/ha over preceding levels. It provided the net returns of ` 68330/ha thereby increasing these by magnitude of ` 7450, 21378 and 51515/ha than obtained with 40 and 20 kg S/ha, and control, respectively.

Interaction:-Net returns in groundnut were also significantly influenced due to combined effect of weed control treatments and S fertilization levels (Table 4.16.1 and Fig. 4.10). Results revealed that integration of 60 kg S/ha either with weed free (W_2S_{60}) or with pendimethalin at 0.75 kg/ha (W_4S_{60}) were found the most superior treatment combinations in getting higher net returns. These combinations provided the net returns of ` 88836 and 86058/ha that were 4899.2 and 4742.9 per cent higher than obtained under weedy check treatment in conjunction with no S application ($W_1S_0$) wherein, the lowest returns of ` 33148/ha were obtained. W_2S_{40}, W_3S_{60} and W_4S_{40} were found the next better and equally effective treatment combinations with regard of increasing net returns.

B: C ratio:-Weed control: It is apparent from the data presented in table 4.16 that B:C ratio in groundnut was significantly improved due to all the weed control treatments than weedy check. The highest B:C ratio of 2.13 was noted under pendimethalin at 0.75 kg/ha that was significantly higher than rest of the treatments. It was followed in the order of one HW at 25 DAS (1.91), weed free (1.88), imazethapyr at 100 g/ha (1.69) and fluazifop-p-butyl at 0.20 kg/ha (1.30) that also represented 176.7, 148.0, 144.1, 119.5 and 68.9 per cent increase in B: C ratio over weedy check, respectively.

Sulphur levels:- Further reference to data revealed that successive increase in level of S increased the B : C ratio significantly over lower levels (Table 4.16). The maximum B:C ratio of 2.25 was obtained with the application of S at 60 kg/ha that was 10.9, 42.5 and 29.5 per cent more than obtained under 40 and 20 kg S/ha and control, respectively.

Interaction:-B.C ratio in groundnut was also influenced due to combined effect of weed control and S fertilization (Table 4.16.1). Data indicated that the maximum B:C ratio of 2.90 was obtained when pendimethalin at 0.75 kg/ha was combined with 60 kg S/ha (W_4S_{60}). It was accompanied by W_3S_{60} (2.63), W_4S_{40} (2.63) and W_2S_{60} (2.59) treatment combinations that were found at par among themselves but significantly superior over rest of the treatment combinations.

Table 4.17 Effect of weed control and sulphur levels on net returns (`/ha) and B:C ratio

Treatments	Net returns (/ha)	B:C ratio
Weed control		
Weedy check	20955	0.77
Weed free	63546	1.88
One HW at 25 DAS	56764	1.91
Pendimethalin @ 0.75 kg/ha	62319	2.13
Fluazifop-p-butyl @ 0.20 kg/ha	37733	1.30
Imazethapyr @ 100 g/ha	48146	1.69
SEm±	1771	0.06
CD (P = 0.05)	5580	0.18
CV (%)	12.72	12.60
Sulphur levels (kg/ha)		
0	16815	0.57
20	46952	1.58
40	60880	2.03
60	68330	2.25
SEm±	864	0.04
CD (P = 0.05)	2293	0.10
Interaction (WxS)	Sig.	Sig.
CV (%)	7.60	10.15

Sig. = Significant

Correlation and regression studies: -Correlation coefficients and regression equations were worked out to study the relationship of pod yield with weed dry matter, nutrient depletion by weeds, crop dry matter, yield attributes, shelling percentage and nutrient uptake by crops which are summarized in table 4.17. The results of correlation coefficients indicated that pod yield of groundnut was significantly and negatively correlated with weed dry matter (r = -0.520) and N, P and K depletion by weeds (r = -0.493, -0.491 and -0.495) at harvest and significantly and positively correlated with crop dry matter at harvest (r = 0.969), number of pods/plant (r = 0.997), kernels/pod (r = 0.988), seed index (r = 0.963), shelling percentage (r=0.972) and N, P and K uptake by crop (r = 0.993, 0.996 and 0.993). Linear relationship appeared to exist between pod yield and independent variables. The regression equations (Table 4.17) showed that every unit increase in weed dry matter and N, P and K depletion by weeds at harvest stage decreased the pod yield of groundnut by 0.322, 18.373, 118.030 and 21.530 kg/ha, respectively. On the other hand, every unit increase in crop dry matter at harvest, number of pods/plant, kernels /pod, seed index, shelling percentage and N, P and K uptake by crop substantially increased the pod yield by 3.872, 95.414, 810.256, 63.589, 120.465, 11.531, 47.846 and 101.346 kg/ha, respectively.

Optimum dose of sulphur:- Response of pod yield to varying levels of sulphur was worked out and found to be the quadratics (Fig. 4.11). The functional form of yield response of sulphur is given in table 4.18. The perusal of data showed that the economic optimum level of sulphur was found to be 58.47 kg/ha with its corresponding pod yield of 1986.0 kg/ha.

Table 4.18 Correlation coefficients and linear regression equations showing relationship between pod yield (kg/ha) and independent variables (X)

S. No.	Independent variables (X)	Correlation coefficients (r)	Regression equations ($Y = a + b_{yx}.X$)
1.	Weed dry matter at harvest (kg/ha)	-0.520**	$Y = 1861.293 + -0.322\ X_1$
2.	N depletion by weeds at harvest (kg/ha)	-0.493*	$Y = 1859.920 + -18.373\ X_2$
3.	P depletion by weeds at harvest (kg/ha)	-0.491*	$Y = 1853.945 + -118.030\ X_3$
4.	K depletion by weeds at harvest (kg/ha)	-0.495*	$Y = 1867.498 + -21.530\ X_4$
5.	Crop dry matter at harvest (kg/ha)	0.969**	$Y = -5.199 + 3.872\ X_5$
6.	Number of pods/plant	0.997**	$Y = -5.101 + 95.414\ X_6$
7.	Number of kernels/pod	0.988**	$Y = -2022.883 + 810.256\ X_7$
8.	Seed index (g)	0.963**	$Y = -2422.241 + 63.589\ X_8$
9.	Shelling percentage	0.972**	$Y = -6763.887 + 120.465\ X_9$
10.	N uptake by crop (kg/ha)	0.993**	$Y = 398.996 + 11.531\ X_{10}$
11.	P uptake by crop (kg/ha)	0.996**	$Y = 372.896 + 47.846\ X_{11}$
12.	S uptake by crop (kg/ha)	0.993**	$Y = 462.746 + 101.346\ X_{12}$

* Significant at 0.05 % level of significance ** Significant at 0.01 % level of significance

Table 4.19 -Pod yield (Y) as a function of sulphur fertilization ($Y = b_0 + b_1\ X\ b_2\ X^2$)

Study parameters		Values
1. Partial regression coefficients		
b_0		921
b_1		35.975
b_2		-0.30375
2. Coefficients of multiple correlation (R)		0.9976
3. Optimum level (kg/ha)		58.469
4. Yield at optimum level (kg/ha)		1986.02
5. Response of optimum level (kg/ha)		1065.02

Note:-The yield, S levels, responses and intercepts are given in kg/ha * Significant at 5% level of significance ** Significant at 1% level of significance

IV. CONCLUSION

In the course of presenting the results of the field experiment entitled "Efficacy of Herbicidal Weed control in groundnut [*Arachis hypogaea* (L.) Wilczek]" at Varying Level of Sulphur, significant variation in the criteria used for evaluating the treatments were observed due to the effect of different treatments. In the ensuing pages, it is endeavored to discuss the significant events or those assuming a definite pattern in respect of various parameters studied, so as to establish cause and affect relationship in the light of available evidences and literature.

Effect of weed control:-Weed density and weed dry matter:-Regular weed survey during the course of experimentation showed that groundnut crop was heavily invaded by broad leaf and some grassy weeds immediately with the crop emergence (Table 4.1). The prominent dicot weed species found to infest the experimental crop were *Amaranthus spinosus, Amaranthus viridis, Phyllanthus niruri, Euphorbia hirta, Trianthema portulacastrum* and *Verbesina encelioides*, whereas, *Cyperus rotundus, Cynodon dactylon, Dactyactenium aegypticum* and *Cenchrus biflorus* were the major narrow leaf weed species noted to invade the crop at later stages of growth and in comparative low intensity. The results indicated that all the weed control treatments caused significant reduction in weed density and dry matter accumulation of weeds at all stages of crop in comparison to weedy check treatment which was noted to be the most severely infested with weeds (Table 4.2 and 4.3). The highest weed density of 46.58 per 0.25 m^2 was observed in weedy check plot at 35 DAS that declined to 39.13 at 70 DAS and 28.99 at harvest stage. This could be ascribed possibly to the severe competition for moisture, nutrients, space, light, shadiness and short life of weeds resulting in exterminating of some species. The weed dry matter production of 946.0 kg/ha recorded at 35 DAS under treatment increased exponentially to 2284.9 kg/ha at 70 DAS and 2729.0 kg/ha at harvest. This profound increase in density and dry matter production of weeds under weedy check treatment might be attributed to uninterrupted growth of weeds throughout the crop season coupled with greater competitive ability than crop that was almost smothered due to fast growing of weeds. Heavy weed infestation and dry weight of weeds under unweeded control in groundnut has also been reported by Ahmed *et al*. (2008). After weed free, application of various herbicides *viz*., pendimethalin at 0.75 kg/ha (PE), imazethapyr at 100 g/ha (PE) and fluazifop-p-butyl at 0.20 kg/ha at 25 DAS also led to significant reduction in weed population and their dry matter at all the stages of crop growth in comparison to weedy check. However, these herbicides varied in their performance among themselves, too. The magnitude of weed control varied significantly between herbicides and HW at 25 DAS. Pre emergence application of pendimethalin at 0.75 kg/ha recorded mean density of 2.64, 2.42 and 2.21 per/m^2 and weed dry matter of 140.2, 324.3 and 457.2 kg/ha at 35 and 70 DAS and at harvest stages, respectively and thus emerged as the most effective treatment by controlling the weeds to the tune of 85.18, 85.81 and 83.22 per cent at these stages than weedy check. However, it was found at par with one HW at 25 DAS. Application of imazethapyr at 100 g/ha (PE) was observed to be the next superior herbicidal treatment. It represented 81.6, 78.1 and 74.3 per cent reduction in dry matter of weeds at 35, 70 DAS and harvest stages of than unweeded control, respectively. These results are in agreement with the finding of kumar *et al*. (2004) in greengram. Performance of fluazifop-p-butyl at 0.20 kg/ha at 25 DAS stage in reducing the density and dry matter of weeds was comparative poor than above described herbicides. It registered 66.4 and 67.3 per cent reduction in density and dry weight of weeds at harvest stage over weedy check treatment, respectively which is in the line of that reported by Ahmed *et al*. (2008) in groundnut. The extent of weed control achieved with these herbicides seems to be due to their phytotoxic action on weeds. Being a dinitroaniline, pendimethalin exerts it herbicidal effect by inhibiting root and shoot growth of weed species when absorbed by them. The inhibition of root growth is a direct and the most spectacular observable symptom following its root absorption. Reduced shoot growth is probably a secondary effect caused by limited root growth. Disruption of ATP formation either by interfering with energy generating mechanism or by blocking the energy transfer mechanism of mitochondria or by both is considered to be the primary mode of action of herbicides mainly the pendimethalin in susceptible plant species (Wang *et al*., 1974). The adverse effect on RNA, DNA and protein synthesis and enzyme activities appears to be secondary. It effectiveness can be further attributed to the fact that it controls broad leaf weeds more effectively than grasses. In the present study, the dicots were for dominating than monocots. Hence, the total weed control due to this herbicides was on superior side. Pendimethalin is known to be absorbed by germinating weeds and disrupts the cell division, especially mitotic prosess mostly in meristematic tissue of weeds which are responsible for lateral and secondary root formation (Ashton and crafts, 1973). Hence, thus it is fairly conceivable that such inhibitory effects of pendimethalin might have reduced the weed population and weed dry matter production. The results are in close conformity with finding of Kumar *et al*. (2004) in greengram. Fluazifop-p-butyl is a post-emergence phenoxy herbicide. It is absorbed rapidly through leaf surfaces and quickly hydrolyzes to fluazifop acid. The acid is transported primarily in the phloem and accumulated in the meristems where it disrupts the synthesis of lipids in susceptible species (Urano 1982; Erlingson 1988). Fluazifop-p-butyl inhibits acetyl CoA carboxylase (ACCase), an enzyme that catalyzes an early step in fatty acid synthesis. Lipids are important components of cellular membranes and when they cannot be produced in sufficient quantities, cell membrane integrity fails, especially in regions of active growth such as meristems. It kills annual and perennial grasses but does little or no harm to broad leaved plants. In the environment, fluazifop-p-butyl is degraded primarily through microbial metabolism and hydrolysis. Similar results have been also reported by Sukhadia *et al*. (1998) in groundnut. Imazethapyr is a selective and systemic herbicide which used for effective control of annual and perennial grasses and broad leaved weeds in soybean and other crops as pre plant incorporation, pre emergence as well as post emergence situation. Being an imidazolinone, it exerts its herbicidal effect by inhibiting root and shoot growth of susceptible weed species as it is absorbed by roots and foliage. From there, it is translocated to xylem and phloem and gets accumulated in meristematic regions. Imazethapyr inhibits the biosynthesis of AHAS/ALS enzyme, catalyses the synthesis of three branched chain amino acids viz., valine, leucine ad isolucine. The reduction in synthesis of these amino acids leads to disruption of protein and DNA synthesis (Dekker and Duke, 1995). Its selectively in soybean and peanuts is attributed to rapid detoxification via hydroxylation and glycosylation. Effective control of weeds in soybean using imazethapyr has also been reported by Shete *et al*. (2007). Dhaka (2011) also found highest weed control efficiency in sesame using this herbicide. One hand weeding done at 25 DAS also showed statistically equivalence with pendimethalin at 0.75 kg/ha (PE) in reducing the density and dry weight of weeds. It recorded 84.0, 83.1 and 80.9 per cent and also reduced the weed dry matter by magniude of 84.2, 83.5 and 80.0 per cent at 35 and 70 DAS and at harvest stages, respectively than weedy check (Table 4.2 and 4.3). The superiority of this treatment can be attributed to the fact that most of the weeds that appeared upto 25 DAS were completely irrespective of their nature and crop-weed competition reduced in the early stage of the crop growth. Therefore, the crop attained sufficient canopy to smother the subsequent flushes of weeds. Efficient management of weeds in groundnut by hand weeding has also been reported by kumar *et al*. (2004) in greengram. Performance of all the three herbicidal treatments that in regard of reducing weed density and dry matter was better (Table 4.2 and 4.3). Pre emergent pendimethalin at 0.75 kg ha/ha was found the most effective method of weed control. Imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha stood the next. The superiority of pendimethalin and imazethapyr treatments could mainly be ascribed to the fact that these herbicides prevented the germination and emergence of weeds during initial stage of crop growth. Whereas, application of fluazifopp-p-butyl at 25 DAS controlled the emerged weeds to a certain extent before critical crop-weed competition period.

Crop growth parameters:- Perusal of data revealed that different weed control treatments evaluated study for their efficacy were noted to differ significantly in their effect on periodical crop dry matter production, number of nodules and fresh and dry weight of nodules/plant in groundnut (Table 4.5 and 4.6). The variation among weed control treatments in their effect on growth parameters of crop has been found to be associated with almost similar variation in weed control. All the treatments significantly enhanced these growth characters of crop at most of the stages over weedy check plots. After weed free, the highest crop dry matter at harvest was recorded by pendimethalin at 0.75 kg/ha treatment which registered 58.6 and 31.5 per cent increase over weedy check and fluazifop-p-butyl at 0.20 kg/ha treatments. It also resulted significant improvement in number and fresh and dry weight of nodules/plant to the extent of 38.9, 43.0 and 33.9 per cent, respectively over weedy check. Application of imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha were found the next superior herbicidal treatments in improving these growth characters of groundnut. One HW at 25 DAS was noted to be the next better and statistically similar treatment to pendimethalin at 0.75 kg/ha which recorded 49.4 per cent more dry matter at harvest and 28.9, 34.0 and 29.0 per cent higher nodules and fresh and dry weight of nodules/plant than weedy check. Significant increase in growth attributes by one hand weedings has also been reported by Raman and Krishnamoorthy (2005). On the other hand, Bhalerao *et al.* (2011) observed superiority of pendimethalin/ fluchloralin + hand weeding in groundnut. The improvement resulted by aforesaid treatments in growth attributes of crop seems to be on account of their direct impact on reduced weed density and periodical weed dry matter production as a result of which manifold reduction in crop–weed competition occurred. The comparative weed free environment provided by these treatments minimized the crop-weed competition to the extent of their efficacy in weed control that led to better growth of crop in terms of dry matter production and nodulation. Weed free environment also saved the growth inputs like moisture, nutrients, light and space and provided better edaphic and nutritional environment in the root zone, as a consequence, inhanced the growth of groundnut significantly as compared to unweeded control. Whereas, uncontrolled growth of weeds throughout the growing season of the crop in weedy check plot arrested the growth due to severe crop-weed competition. One HW at 25 DAS treatment also improved physical condition of the soil by making it loose and porous and provided greater aeration that might have encouraged the proliferation and establishment of lateral roots. The findings of the investigation are in close agreement with Bhalerao *et al*. (2011) who found that two hand weedings as well as pendimethalin / fluchloralin at 1.0 kg/ha foolwed HW at 15 DAS treatments were equally effective in growth characters of groundnut.

Yield attributes and yield:-It is evident from the results that all the weed control treatments evaluated in present investigation differed significantly in their effect on yield attributing characters like number of pods/plant, number of kernels/pod and seed index and grain, straw and biological and kernels yields, shelling percentage and harvest index but found significantly superior in comparison to weedy check treatment (Table 4.7 and 4.8). The variation in these treatments with regard to above parameters again appears to be directly associated with the similar variation in weed control and growth characters of groundnut. The maximum values of most of these parameters were achieved with weed free treatment where weed growth was allowed not at all throughout the growing season. It was followed by pendimethalin at 0.75 kg/ha treatment that recorded the maximum number of pods/plant (19.24) kernels/pod and seed index. It also increased the pod and haulm yield by magnitude of 877 and 1668 kg/ha over weedy check treatment and recorded 34.71% and harvest index and 71.36% per cent shelling percentage. Because of differential competitive abilities of different weed species found in experimental fields, it has been further established that for similar weed densities, a composite stand of weed species is always more competitive than solid stand of single weed species. One HW at 25 DAS and Application of imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg ha were noted to be the next superior weed control treatments. So far as yield attributes and yield of groundnut is concerned, these treatments resulted 79.1, 59.1, and 37.4 per cent increase in pod yield, 82.2, 60.1 and 44.9 per cent in haulm, 81.1, 59.9 and 42.2 per cent in biological yield and 97.5, 71.3 and 43.7 per cent in kernel yield, respectively than obtained under weedy check. The higher pod and haulm yield obtained with either of these treatments could be better explained by their effectiveness in weed control in comparison to weedy check. These superior treatments kept the crop almost weed free of weeds upto 30-35 DAS which in turn resulted to significant reduction in competition for nutrients and other growth resources by weeds as a consequence of which reduction in weed dry matter and nutrient depletion by weeds was obtained. Reduced crop-weed competition under these treatments thus saved a substantial amount of nutrients for crop that led to profuse growth enabling the crop to utilize more soil moisture and nutrients from deeper soil layers. These edaphic factors were more pronounced in one HW treatment as it improved the tilth by making the soil more vulnerable for the plants to utilize water and air. All these favourable effects of weed control treatments resulted significant increase in various yield attributing characters of groundnut viz., number of pods/plant, kernels /pod and seed index by providing better source sink relationship. The higher values of yield attributes coupled with the higher crop dry matter recorded under these treatments might be the most probable reason of higher pod yield. The increase in pod yield of groundnut with these treatments was also largely due to high harvest indices that showed high partitioning coefficient towards sink in the weed free environment. In the presence of weeds, although the vegetative growth occurred to a level but the sink was not sufficient enough to accumulate the meaningful food assimilates translocating towards pod formation. The results of the present study are in close conformity with the finding Chin and pandey *et al.* (1991) in blackgram and Bhale *et al.* (2012) in groundnut who noted superiority of one hand weedings and pendimethalin with regard to yield attributes and yield. Under present investigation, there existed a significant and positive correlation between crop dry matter, pods/plant, kernels/pod, shelling percentage, seed index and N, P and S uptake with pod yield ($r=0.969^{**}$, 0.997**,0.988^{**}, 0.963^{**}, 0.972^{**}, 0.993^{**}, 0.996^{**} and 0.993^{**}) and significant and negative correlation between weed dry matter and N, P and K depletion by weeds with pod yield of groundnut ($r= -520^{**}$, 0.493^{**}, 0.491^{**} and 0.495^{**}) that further conferms the finding of the present investigation. The regression studies also showed that a unit decrease of 1.0 kg/ha in weed dry matter or N, P and K depletion by weeds increased the pod yield of groundnut by 0.251, 1.504, 9.021 and 1.643 kg/ha, respectively. It can be further explained with the fact that weeds remove heavey toll of nutrient from the soil and that the removal of weeds allowed the crop to absorb the nutrient at accelerated rates. Relatively poor yield and yield attributes were recorded with the application of fluazifop-p-butyl and imazethapyr treatments than pendimethalin and one HW treatments that might be attributed to the poor growth obtained under these treatments. These treatments could not reduce the crop-weed competition to the level obtained under superior treatments. Furthermore, the most severe crop-weed competition throughout the crop season due to unrestricted weed growth under weedy check plots increased the depletion of nutrients and moisture by weeds, thus adversely affecting the crop growth. At the same manner time, it also declined the translocation of photosynthates towards seed formation affecting yield attributes adversely, which is turn reduced the yield to the lowest level. These results are strongly supported with the finding of Dhaka (2011) in sesame and Chaitanya *et al*. (2013) in groundnut.

Nutrient concentration and depletion by weeds:-It is clear from data that the maximum depletion of 45.44, 7.06 and 39.26 kg N, P and K/ha by weeds at harvest was found in the plots left unweeded throughout the crop season that was significantly higher over rest of the weed control treatments (Table 4.10 to 4.11). Whereas, after weed free, the lowest depletion of 8.63, 1.29 and 7.58 kg/ha was recorded with pendimethalin at 0.75 kg/ha treated plots that was closely accompanied by one HW at 25 DAS treatment. These two treatment thus saved the maximum quantity of 36.81 and 35.24 kg N, 5.77 and 5.51 kg P and 31.68 and 30.31 kg K/ha, upto harvest as compared to control. The drastic reduction in nutrient depletion by weeds under these treatments might be directly associated with the corresponding reduction in dry matter production by weeds due to effective control and suppression of weed growth by crop (Dhaka, 2003). Application of imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg ha were found the next better treatments in reducing the nutrient depletion by weeds. But, imazethapyr showed some marginal superiority over fluazifop-p-butyl at 0.20 kg/ha. These treatments were found significantly superior in reducing the nutrient depletion over weedy check but remained inferior to above described treatments. These treatments could not control the weeds throughout the growing season of the crop as efficiently as controlled by one HW and application of pendimethalin at 0.75 kg/ha treatments. The greater biomass of weeds so accumulated under these treatments might be attributed as the major reason for higher nutrient depletion. Results further showed that some of the weed control treatments bring about significant variation in nutrient concentration of weeds at harvest stage which might be owing to the very high competition for nutrient absorption among the fast growing weeds themselves and crop plants to meet their growth requirements. Due to sparse population of weeds in other treatments, nutrient concentration in their dry matter was found more or less similar. These results are in accordance with those reported by Savu *et al*.(2010) in groundnut.

Nutrient concentration, uptake and quality:-N, P and S concentration in kernel and haulm were significantly improved due to most of the weed control treatments (Table 4.12 to 4.14). As weedy check plots were heavily invaded by a number of fast growing weed species than crop right from emergence of crop upto harvest stage, the increasing rates of N, P and S depletion by rapidly growing weeds at subsequent stages under weedy check and some other treatments witnessing poor weed control efficiencies, offered maximum crop-weed competition for nutrients which is turn marginally but significantly reduced their concentration in kernel and haulm at harvest under these treatments. Data further indicated that protein content in groundnut kernels was improved over weedy check due to all the weed control treatments except fluazifoop-p-butyl at 0.20 kg/ha (Table 4.15). As protein in kernel is a function of its N concentration, therefore higher concentration N in kernels under these superior treatment seems to be the only reason of attaining higher protein content. All the weed control treatments except fluazifop-p-butyl at 0.20 kg/ha also recorded significantly higher oil content in kernel than unweeded control (Table 4.15). Remaining at par among themselves, the highest oil content of 43.87 per cent was achieved with weed free followed by pendimethalin at 0.75 kg/ha (43.85%) and one HW at 25 DAS (42.86%) treatments. Improvement in oil content under these superior treatment appears to be directly associated with the higher seed index under these treatments that produced bolder kernel under weed free conditions than weedy check. Favourable effect of weed control using mechanical and herbicidal measures on protein and oil content of groundnut has also been reported by Suresh *et al*. (2010). Higher oil content coupled with higher kernel yield further resulted significant more oil yield under these superior treatments. Data further indicated that all the weed control treatment resulted significantly enhancement in uptake of N, P and S comparison to weedy check (Table 4.12 to 4.14). The maximum uptake of 137.92 kg N, 33.67 kg P and 15.15 kg S/ha were achieved under weed free treatment. Pendimethalin at 0.75 kg/ha and one HW at 25 DAS were the next better and equally effective treatments having 159.2 and 147.5 per cent higher N; 144.5 and 124.8 per cent P and 166.9 and 142.8 per cent higher S uptake by crop than weedy check treatment, respectively. Imazethapyr and fluazifop-p-butyl recorded comparatively lower but significantly higher nutrient uptake than weedy check. The superiority of the treatments stated above might be ascribed to the fact that these treatments controlled and suppressed the weed growth very effectively and provided weed free environment to the crop for longer time to utilize the available and applied nutrients under reduced crop-weed competition. Thus, increase in dry matter and pod yield production with a concomitant increase in nutrient concentration seemed to be directly responsible for greater uptake of nutrients by crop under these treatments. Significant and positive correlation existed between N, P and S uptake and kernel yield of groundnut also lend spport to the findind of the present investigation (Table 4.17). Similar favourable effects of weed control treatments on nutrient concentration and uptake has also been reported by Rana and Pal (1999) in pigeonpea and Savu *et al*. (2005) in groundnut.

Weed control efficiency and weed competition index:-All the weed control treatments exhibited great variation in their efficiency to control the weeds (Table 4.4) and weed competition indices (Table 4.9). The weed control efficiency at harvest and weed competition indices ranged between 67.28 to 83.22 and 8.26 to 31.86 per cent, respectively. Application of pendimethalin at 0.75 kg/ha (PE), one HW at 25 DAS and imazethapyr at 0.20 kg/ha were found to be among more effective treatments that controlled the weeds to the extent of 83.22, 79.96, and 74.27 per cent, respectively. This variation in weed control efficiency is directly associated with the amount of weed dry matter accumulated under these treatments. By removing the initial flushes weeds, one HW at 25 DAS reduced the weed growth more efficiently during most of the crop growth period. On the other hand, inhibition of germination of weeds and their growth following application of different herbicides might have reduced the growth of weeds through arresting cell division and elongation and thus causing mortality of weeds. These seem to be the most spectacular reasons of accumulating lesser dry weight of weeds and as a consequence of higher weed control efficiencies. Weed competition index was also reduced due to these treatments in comparison to control. The variation in crop-weed competition under different treatments is associated with similar variation in weed dry matter production and the corresponding nutrient depletion by weeds that was eventually reflected in the pod yield, Data presented in table 4.9 indicated that pendimethalin at 0.75 kg/ha recorded the lowest weed competition index of 8.26 per cent, only as against the maximum of 50.43 per cent observed under weedy check. Application of pendimethalin at 0.75 kg/ha, one HW at 25 DAS and imazethapyr at 100 g/ha were found the next better treatments in lowering weed competition index. Inefficient control of weeds by fluazifop-p-butyl at 0.20 kg/ha treatment was reflected in higher weed competition index obtained under this treatment. The higher weed dry matter production and nutrient depletion by weeds and corresponding reduction in pod yield appeared to be directly associated with variation in weed competition indices among different treatments. The results are in close agreement with the findings of Vega *et al*. (2000) in soybean and Bhale *et al*. (2012) in groundnut.

Economics:-All the weed control treatments provided significantly higher net returns and B:C ratio in comparison to weedy check treatment, which is obviously due to higher kernel and haulm yields obtained with these treatments (Table 4.16). Weed free treatment fetched the maximum net returns of ` 63546/ha with a B:C ratio of 1.88 thereby, increasing the net returns by a margin of ` 16252/ha over weedy check.

Pendimethalin at 0.75 kg/ha, one HW at 25 DAS, imazethapyr at 100 g/ha and fluazifop-p-butyl at 0.20 kg/ha were observed to be the next superior treatments that increased the net returns by ` 41364, 35809, 27191, and 16778/ha respectively, corresponding with B:C ratio of 2.13, 1.91, 1.69 and 1.30. The higher B:C ratio achieved under superior treatments seems to be directly associated with the higher kernel and haulm yields and higher returns per rupee investment than poor yielding treatments. The lowest pod yield achieved under weedy check treatment was eventually reflected in the lowest net returns (20955/ha) and B:C ratio (0.77). Results of the present investigation corroborate the findings of Shankaranarayana (2000) and Bai *et al.* (2000) in groundnut.

Effect of sulphur:-Weed density and weed dry matter:- Results indicated that application of sulphur did not cause any significant variation in weed density and weed infestation at all stages of crop growth (Table 4.2). Progressive increase in level of sulphur produced significantly higher weed dry matter up to 60 kg S/ha at 35, 70 DAS and harvest stages over proceeding levels (Table 4.3). This increase in dry matter of weeds might be ascribed to the availability of S in ample amounts leading to better nutritional environment in the rhizosphere for sustained growth and development of weeds. As sulphur is one the most important elements in relation to growth and development of plants, increased availability of it in soil due to external addtition might have been directly responsible for the huge amount of weed biomass production at different stages of crop growth. The better availability of S achived by its increasing addition to soil sustained the growth of large number of rapidly growing weeds that would have otherwise been exterminated away under poor fertility levels. These finding are in close conformity with those reported by Chaubey *et al.* (2003).

Growth attributes:-Groundnut crop responded favourable to S application in terms of number of nodules, fresh and dry weight of nodules/plant and dry matter accumulation. These parameters increased linearly with corresponding increase in levels of S upto 60 kg/ha that was by and large significant over control, 20 and 40 kg S/ha at later stage of crop growth (Table 4.5 and 4.6). It is because of the fact that application of sulphur has been reported to improve not only the availability of sulphur itself but of other nutrients, too, which are considered important for the growth and development of plant. The improvement in crop growth and nodulation with sulphur application could be ascribed ti its pivotal role in regulation of the metabolic and enzymatic process including photosynthesis, respiration and legume-Rhizobium symbiotic nitrogen fixation which reflected in increase yield. Sulphur has also been reported to help in lowering the soil pH which is the main reason for greater availability and mobility of nutrient especially of P, Fe, Mn, and Zn (Hilal *et al.*1992). Sulphur in the form of sulphate is involved in various metabolic and enzymatic activities of plants. It is also a constituent of glutathione, a compound supposed to play part in plant respiration and synthesis of oils (Jordon and Reisenaur, 1957). Further , sulphur also plays a vital role in chlorophyll formation as it consititutes succynyl Co-A which is involved in synthesis of chlorophyll (Pirson, 1955). It engages in activation of a number of enzymes participating in dark reaction of photosynthesis via improvement in general and their activation at cellular level by promoting greater photosynthesis and merismetic activity seemed to have stimulated vegetative growth of crops in terms of dry matter accumulation, number and weight of nodules/plant significantly the similar result were also reported by Singh *et al*. (2008) in groundnut. The profound influence of sulphur fertilization on number of nodules and dry matter could be attributed to increased metabolic processes in plants which seems to have promoted meristematic activities causing higher apical growth and expansion of photosynthetic surface. Thus, increase availability of S as a result of fertilization in the soil which was otherwise deficient in it (Table 3.3) as well as other nutrients due to its synergistic effect might have led to improvement in the concentration and uptake of this nutrient (Table 4.12 to 4.14). This increased supply of S and associated nutrients might have helped in rapid cell multiplication and higher chlorophyll content thereby accelerating photosynthesis rate and eventually more supply of assimilates to plants that in turn increase the growth in terms of greater canopy, height and accumulation of dry matter at the successive growth stages. The higher content of sulphur in plants is known to have role in better development and thickening of xylem and collenchymas tissues. Such favourable effects might have resulted in stronger stem thereby increasing the number of nodules/plant. The improvement in overall vegetative growth of the crop with the application of sulphur in the present investigation is in cognizance with the finding of Battacharya *et al* (1997) and Kadam *et al.* (2000) in groundnut and Allam (2003) in sesame.

Yield attributes, yield and economics:- Every increase in level of sulphur up to 60 kg/ha recorded significant improvement in pods/plant, number of kernels/pod, seed index and shelling percentage over preceding levels (Table 4.7). The improvement in yield attributes due to S fertilization seems to be due to overall improvement due to crop growth as a consequence of balanced nutritional environment as discussed above. The probable reason could be efficient and greater partition of metabolites and adequate translocation of nutrients towards the developing reproductive structures *i.e.* sink. The improved growth due to S fertilization coupled with increased photosynthesis on one hand and greater mobilization of photosynthates towards reproductive structures. On the other, might have been responsible for significant increase in yield attributes of groundnut. Watering and Patrick (1975) also reported that improvement in yield parameters was attributed to diversion of greater proportion of assimilates to the developing pods due to increased sink strength reflected through its larger demand of photosynthates. Supply of sulphur in adequate amount also helps in the development of floral primordial i.e. reproductive parts, which results in the development of pods and kernels in plants. Similar finding have also been reported earliar by Patel *et al*. (2009) in groundnut. Pod, haulm and biological yields also showed substantially increase with increasing levels of S up to 60 kg/ha (Table 4.8). As yield of the crop is the cumulative effect of yield determining characters such as pods/plant, kernels/plants and seed index, significantly higher values of these characters might be ascribed as the most probable reason of getting higher pod and haulm yield of groundnut. Significant and positive correlation existed between pod yield and crop dry matter, yield attributing characters and nutrient uptake by crop. Further provide the evidence to the findings of the present investigation (Table 4.17). The increase in haulm yield due to sulphur application might be due to the cumulative effects of increased number of nodules/plant and dry matter production *i.e.* increased growth parameters. The pod and haulm yields combined together showed significant increase in biological yield of groundnut (Table 4.8). Increasing the S level from 0 to 60 kg/ha also provided additional net returns of ` 51515/ha with a B:C ratio of 2.25 over control (Table 4.17) which is primarily due to the higher pod yield with comparative lesser additional cost of S under this treatment. Significant improvement in yield attributes and yield of groundnut due to S fertilization has also been reported by Singh and Singh (2000) and Patel *et al.* (2009).

Nutrient concentration and depletion by weeds:-The highest concentration of N, P and K in weed dry matter was recorded at 60 kg S/ha. Progressive increase in level of S from 0 to 60 kg/ha also showed significantly higher depletion of these nutrients at harvest stage by weed over lower levels (Table 4.10 to 4.11). The increased availability of S in rhizosphere due to its addition led to more and more absorption of this nutrient from the soil to meet the growth requirement of fast growing weeds in comparison to the plots that were poorly fertilized with S or no fertilization was done. It seems the principal reason of higher nutrient concentration in weeds in response to applied S (Table 4.10). The huge amount of weed dry matter with a concomitant increase in its nutrients concentration due to application of 60 kg S/ha appeared to be responsible for increased depletion of N, P and K by weeds.

Nutrient concentration, uptake and quality parameters:- Application of S showed significant variation in N, P, and S concentration in kernels and haulms of groundnut (Table 4.12 and 4.14). The positive influence of S application on concentration in crop appears to be due to improved nutrimental environment in rhizosphere as well as in plant system. The adequate supply of S in early crop season resulted in greater availability of nutrients including P and S and of N in particular in the root zone depth of the soil. Increased availability of these nutrients coupled with accelerated metabolic activities at the cellular level probably might have increased the nutrient uptake and their accumulation in various parts of the plant. This accumulation of nutrients especially S in plant parts possibly with greater metabolism led to greater translocation of these nutrients to reproductive parts of the crop which appears to be the most probable reason of higher nutrient concentration in kernel and haulm due to S fertilization. Nitrogen and sulphur are the main ingredients of protein and increase in their availability increase the utilization of nitrogen for the synthesis of protein (Finalayson et al. 1970). Sulphur synthesized some sulphur containing amino acids like cystine, cysteinin and methionine and resulted increase in protein content (Table 4.15) which is in accordance with the finding of Tathe (2008).The significant variation in S concentration can also be attributed to higher functional activity of roots for longer duration under higher levels of S. Increased biomass production of the crop at harvest in terms of kernel and haulm yield together with higher nutrient concentration might have resulted in significantly higher uptake of N, P, and S by crop due to S fertilization up to 60 kg/ha (Table 4.12 to 4.14). These finding corroborate the result of Poonia *et al.* (2013) in groundnut. Oil content in seed and oil yield also increased significantly as a result of sulphur application (Table 4.15). The increase in oil content due to sulphur fertilization might be the outcome of better availability of nutrients owing to favourable environment created by sulphur application. As sulphur is an integral part of oil, the increased availability of sulphur might have favourably influenced the synthesis of essential metabolism responsible for higher oil content. Sulphur is also known to be involved in increased conversion of primary fatty acids, several enzymes catalyzing metabolic process which promote biosynthesis of lipids. Plants growing in sulphur deficient soil may have a limited capacity of biosynthesis resulting in decreased oil content. In absence of sulphur, carbohydrates are not fully utilized during formation of oil (Nightingale *et al.* 1932). Moreover, the increase in oil content might be due to increase in glucoside, which on hydrolysis produce higher amount of oil. The higher oil yield due to sulphur application is the outcome of higher oil content in kernel and significantly higher pod yield of groundnut. These finding corroborate the results of Sahu *et al.* (2001) Kalaiyarasan *et al.* (2007) observed in groundnut.

Results of the field experiment entitled "Efficacy of Herbicidal Weed Control in Groundnut (*Arachis hypogaea* L.) At Varying Levels of Sulphur" conducted during *kharif*, 2013 presented and discussed in the preceding chapters are summarized here under:

Effect of weed control:-

- The major weed species found to infest the experimental field were *Amaranthus viridis, A. spinosus, Trianthema portulacastrum, Digera arvensis, Dactylotenium aegyptium, Celosia argentia, Cyperus rotundus, Cynodon dactylon* and *Phyllanthus niruri*.
- Pendimethalin at 0.75 kg/ha treatment recorded the significantly lowest weed density at all the stage. This treatment recorded the weed population of 6.47, 5.35 and 4.38 per 0.25 m^2 as against the maximum of 46.58, 39.13 and 28.99 recorded in the plots left unweeded throughout the crop season at 35, 70 DAS and at harvest stages, respectively. It was closely accompanied by one HW at 25 DAS.
- The above mentioned treatments also showed their superiority in lowering the weed infestation in crop to a considered extent in comparison to weedy check at all the stages of observation.
- Reducing the weed dry matter to the extent of 85.8 and 83.4 per cent at 70 DAS and 83.2 and 79.9 per cent at harvest stages, respectively in comparison to weedy check, application of pendimethalin at 0.75 kg/ha (PE) and one HW at 25 DAS were found the most superior and equally effective treatments in controlling weeds.
- Plant stands of groundnut remained unaffected at all the stages due to weed control treatments.
- Growth attributes of groundnut *viz.* dry matter accumulation at all the stages and total number and fresh and dry weight of nodules /plant at 40 DAS stage were significantly enhanced by all the weed control treatments. Weed free, Pendimethalin at 0.75 kg/ha and one HW at 25 DAS proved equally effective and significantly better treatment in these characters.
- All the weed control treatments significantly improved the yield attributing characters of groundnut. After weed free, the maximum number of pod/plant (19.24), kernels/pod (2.16) and seed index (68.39 and 65.90) were obtained with pendimethalin at 0.75 kg/ha that showed statistically equivalence with one HW at 25 DAS treatment.
- After weed free, the highest pod, haulm, biological and kernels yields (1854, 3456, 5310 and 1339 kg/ha) and shelling percentage (71.36%) were obtained with the application of pendimethalin at 0.75 kg/ha treatment. It was found at par with one hand weeding done at 25 DAS treatment wherein, corresponding increase of 79.1, 82.2, 81.1, 97.4 and 10.1 per cent over unweeded control was recorded. Imazethapyr at 100 g/ha was the next superior treatment in improving yield of groundnut. These three treatments also attained significantly higher shelling percentage 71.36, 70.78 and 69.10, respectively than unweeded control, respectively.
- The maximum crop-weed compititon experienced under weedy check treatment drastically reduced the pod yield of groundnut to the extent of 50.43 per cent in comparison to weed free treatment. On the other hand, pendimethalin at 0.75 kg/ha and one HW at 25 DAS witnessed weed competition indices of 8.26 and 11.21 per cent, only.
- N, P and K concentration in weed dry matter at harvest stage was influenced significantly due to some of the weed control treatments. Weed free, pendimethalin at 0.75 kg/ha, one HW at 25 DAS and imazethapyr at 100 g/ha recorded statistically similar but significantly higher concentration of thses nutrients in weeds than weedy check treatment.
- All the weed control treatments also led to significant reduction in nutrient depletion by weeds in comparison to weedy check. The minimum depletion of 8.63 kg N, 1.29 kg P and 7.58 kg K/ha was noted under pendimethalin at 0.75 kg/ha that showed statistical equivalence with one HW at 25 DAS treatment.
- N, P and S concentration in kernel and haulm was significantly augmented due to most of the treatments than weedy check. Weed free. Pendimethalin at 0.75 kg/ha, one HW at 25 DAS and imazethapyr at 0.20 kg/ha were observed to be significantly superior and statistically similar treatments in this regard. These treatments also recorded significantly higher protein content of 23.48, 23.60, 23.98 and 23.04 per cent, respectively in kernel than weedy check treatment.
- As a consequence of higher nutrient concentration and more dry matter accumulation, all the weed control treatments also led to significantly higher uptake of N, P and S by crop in comparison to weedy check. Next to weed free, maximum uptake of 124.72, 31.34 and 13.93 kg N, P and S/ha was noted with pendimethalin at 0.75 kg/ha. Whereas, one HW at 25 DAS registered 147.4, 124.8 and 142.8 per cent higher uptake of these nutrients than control and thus stood at par.
- Remaining at par among themselves, all the treatments except fluazifop-p-butyl at 0.20 kg/ha attained significantly higher oil content in kernel. Weed free, pendimethalin at 0.75 kg/ha and one HW at 25 DAS treatments also increased the oil yield by magnitude of

164.4, 143.0 and 122.3 kg/ha, respectively over weedy check treatment.

- Fetching the maximum net returns of ` 62319/ha and highest B:C ratio (2.13), pre emergence application of pendimethalin at 0.75 kg/ha emerged as the most remunerative weed control treatment. After weed free (` 63546/ha) one hand weeding at 25 DAS also provided 170.8 per cent higher net returns than weedy check with a B: C ratio of 1.91 and thus showed statistical equivalence with pendimethalin at 0.75 kg/ha.
- Weed dry matter production and nutrient depletion by weeds at harvest stage was significantly and negatively correlated with pod yield of groundnut. Whereas, significant and positive correlation existed between pod yield and crop dry matter, yield determining characters and nutrient uptake by crop.

Effect of sulphur levels:-

- Varying levels of sulphur fertilization did not bring any significant variation in weed density and weed infestation at any stage of crop growth.
- Remaining at par with 40 kg S/ha, sulphur fertilization at 60 kg/ha recorded the highest weed dry matter at all the stages.
- Application of 60 kg S/ha significantly enhanced the periodical crop dry matter accumulation, number of nodules and fresh and dry weight of nodules/plant over preceding levels.
- Sulphur fertilization at 60 kg/ha significantly improved the number of pods/plant, to the extent of 8.3, 27.5 and 112.2 per cent, kernels/pods by 3.3, 12.2 and 32.6 per cent and seed index by 5.1, 11.9 and 24.8 per cent, respectively over 40, 20 and 0 kg/ha, respectively.
- Application of S at 60 kg/ha produced the highest pod, haulm, biological and kernel yields of groundnut (1999, 3679, 5678 and 1480 kg/ha) that were significantly higher over lower levels. It also witnessed the sulphur shelling percentage of 73.40. However, harvest index remained unaffected due to S fertilization.
- Application of sulphur at 20 kg/ha in groundnut significantly enhanced the N, P and K concentration in weed dry matter over control; though, the highest concentration of all the nutrients was recorded at 60 kg S/ha.
- The highest depletion of 20.98, 3.18 and 18.09 kg N, P and K/ha was recorded when crop was applied with 60 kg S/ha that was higher by 1.09, 0.14 and 0.59 kg/ha over 40 kg S/ha and 2.42, 0.35 and 1.62 kg over 20 kg and 5.98, 0.89 and 4.94 kg/ha over control, respectively.
- N, P and S concentration in kernel and haulm of groundnut were maximized with S application at 40 kg/ha. However, it were found statistically at par with 60 kg S/ha.
- Every Increase in level of S brought about significantly higher uptake of nutrients by crop upto highest level of 60 kg S/ha. It recorded the maximum uptake of 139.79 kg N, 34.36 kg P and 15.37 kg S/ha which was 178.7, 183.0 and 207.4 per cent more than control, respectively.
- Application of S at 60 kg/ha registered the highest protein content in kernel (23.50%), oil content (45.64%) and oil yield (684.97 kg/ha) of groundnut.
- Application of S at 60 kg/ha fetched the maximum net returns of Rs 68330/ha with a B:C ratio of 2.25. Thus, it provided additional net returns of ` 7450, 21378 and 51515/ha over 40 and 20 and control, respectively.
- Sulphur fertilization at 58.47 kg/ha was noted the optimum level of sulphur corresponding with the pod yield of 1960 kg/ha.

Interactive effect of weed control and sulphur:-

- Pendimethalin at 0.75 kg/ha and one HW at 0.20 kg/ha plots along with no S fertilization (W_4S_0,and W_3S_0) resulted in significantly lower and statistically similar weed dry matter at 70 DAS and harvest and nutrient depletion by weeds at harvest stage of the crop as against the maximum dry matter and depletion recorded with unweeded control combined with 60 kg S/ha fertilization (W_1S_{60}).
- After weed free, integration of S at 60 kg/ha either with pendimethalin at 0. 75 kg S/ha (W_4S_{60}) or one HW at 25 DAS (W_3N_{60}) recorded significantly higher crop dry matter at all the growth stages. Remaining at par with each other, these treatment combination also recorded significantly higher pods/plant that was also comparable with weed free combined with 60 kg S/ha than rest of the combinations.
- Weed free and pre-emergent pendimethalin at 0.75 kg/ha in conjunction with 60 kg S/ha recorded the highest pod (1971 and 1854 kg/ha), haulm (3671and 3456 kg/ha), biological (5643 and 5310 kg/ha) and kernels yield (1453 and 1339 kg/ha) of groundnut but it was found at par with one hand weeding at 25 DAS treatment combined with 60 kg S/ha (W_3S_{60}) that produced pod, haulm biological and kernel yields of 1750, 3259, 5009 and 1254 kg/ha, respectively.
- The maximum uptake of N, P and S by crop at harvest was obtained when weed free and pre emergent pendimelin at 0.75 kg/ha treatments were combined with 60 kg S/ha (W_2S_{60} and W_4S_{60}). These were very closely

accompanied by one HW at 25 DAS along with 60 kg S/ha (W_3N_{60}), wherein N, P and S uptakes of 119.05, 28.81 and 12.67 kg/ha, respectively were observed.

- Weed free alongwith 60 kg S/ha and pendimethalin at 0.75 kg/ha (PE) combined with 60 kg S/ha also provided significantly higher (652.9 and 600.3 kg/ha) oil yields. However, it showed statistically similarity with W_3S_{60} combination.
- pre-emergence application of pendimethalin at 0.75 kg/ha combined with 60 kg S/ha (W_4S_{60}) and weed free treatment along with 60 kg S/ha (W_2S_{60}) proved the most remunerative and equally effective treatment combinations. These combinations provided significantly higher net returns of ` 62319 and 63546 /ha with ratio B: C ratio of 2.13 and 1.88, respectively than rest of the treatment combinations.

Based on one year experimentation, it may be concluded that pre emergence application of pendimethalin at 0.75 kg/ha combined with sulphur fertilization at 60 kg/ha was found the most superior treatment combination for obtaining higher pod yield (2353 kg/ha), net returns (` 86058/ha) and B:C ratio (2.90) from groundnut. Weed free treatment in conjunction with 60 kg S/ha was also found equally effective, hence it can be practised where labour is easily available at cheaper rates. On the basis of production function, application of sulphur at 58.46 kg/ha was worked out to be the optimum dose for groundnut.

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