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Yield and quality of groundnut genotypes as affected by different sources of sulphur under rainfed conditions

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Abstract

A field experiment was conducted to determine the response of groundnut genotypes to sulphur sources at Koont Research Farm of PMAS-Arid Agriculture University Rawalpindi under rainfed conditions during April 2013. Experiment was comprised of four groundnut genotypes viz. Bari-2011, Golden, Bard-92 and PG-1058 and three sources of sulphur (S) SSP (45 kg ha^{-1}), SOP (45 kg ha^{-1}) and gypsum (400 kg ha^{-1}) with control. Results revealed that genotype Bari-2011 gave best performance for number of plants m^{-2}, number of pegs plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, seed index, seed yield and harvest index. Sources of sulphur depicted statistically significant results for yield and quality parameters of groundnut genotypes. Among sources of sulphur SSP revealed best performance for all studied with an increase of 81.5% in grain yield compared to control. Among interactive effect of genotypes and sulphur fertilizers, genotype Bari-2011 along with SSP gave maximum results for all parameters studied.

Keywords: Groundnuts, genotypes, sulphur sources, yield

Introduction

Groundnut (*Arachis hypogaea* L.) is a conventional oil seed crop grown in rainfed areas of Punjab, Pakistan (Nazir *et al.*, 2011). It's seeds contain 43-55 % oil contents (Din *et al*., 2009), 24-26 % protein, 45-48 % fat, 3 % fiber and 15-18 % carbohydrates (Shokunbi *et al*., 2012). It is a dietary source of calcium, magnesium, iron, zinc, phosphorus, vitamin E, riboflavin, thiamine and potash. This crop is also used in the form of fodder, seeds, straw and hay (Smith, 2002). Groundnut serves as an important source of food and energy. It can be used as food (cooking oil, raw, roasted) feed (green material, straw, seed pressings) and used in industry as a raw material (Onyeike and Oguike, 2003). Use of groundnut reduces the risk of cardiovascular disease (Etherton *et al*., 1999), breast cancer, colon and prostate (Awad *et al.,* 2000). It may also reduce osteoporosis (Messina, 1999), diabetes (Jiang *et al.*, 2000). Groundnut is associated with many metabolic benefits in reducing obesity and metabolic syndrome (Coates and Howe, 2007), it also increases the soil fertility due to its leguminous nature by fixing atmospheric nitrogen (Hossain *et al.*, 2006).

Sulphur (S) is a secondary nutrient for plant growth and development (Jamal *et al*., 2010). It is least plentiful essential macronutrient in plants. For the formation of organic metabolites nitrogen and sulphur are needed which are absorbed from soil in the form of sulphates (SO_4^{-2}) through roots. It plays very important role in catalytic and electrochemical functions of biomolecules in the cells (Saito, 2004). Positive response of sulphur application has been observed in groundnut (Mishra *et al.,* 1999). It improves dry matter, plant height, number and weight of seed, seed yield and biological yield (Poonia, 2000). The application of elemental sulphur resulted significantly high yield, micro-nutrient content and uptake in groundnut (Sisodiya *et al*., 2017). Significantly high increase in number of pods and seeds /plant, weight of pods and seeds /plant, 100-seed weight as well as seed oil and protein yields was observed in another study dealing with sulphur application and foliar spraying with Zinc and Boron on yield, yield components, and seed quality of Peanut (EL-Kader and Mona, 2013).

Several studies resulted that application of different sulphur containing fertilizers exposed differential impact on the growth, development and production of crops. Single super phosphate (SSP) is an important source of sulphur. It has substantial effect on grain yield, total biological yield, sulphur concentration in grain, total sulphur uptake, grain protein content, oil content and oil yield (Chattopaddhyay, 2012). Sulphate of potash (SOP) is another key source of

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sulphur. It increases the pod yield, kernal yield, individual grain weight and oil content (Ramdevputra *et al*., 2010, Dwivedi and Bapat, 1998). Gypsum ($CaSO_4.2H_2O$) is a general name for a mineral compound called calcium sulphate. Gypsum has equal or better effect on groundnut as other S containing fertilizers. Formation of vitamin and chlorophyll is affected by the application of gypsum (Ghosh *et al*., 2000). The yield and quality of oilseed crops are decreasing due to deficiency of sulphur as it is essential with nitrogen for protein and enzymes synthesis. Moreover sulphur also forms part of cysteine, methionine, amino acids and many secondary compounds in plants. The quality of crop may also be influenced by the amount and kind of these compounds, it may increase the nutritional value for human and animals (Ahmad and Abdin, 2000).

The current study was conducted to evaluate the effect of different sources of sulphur on growth, yield, quantity and quality of oil contents in different groundnut genotypes under rainfed conditions.

Materials and Methods

Experimental site

To evaluate the yield and yield attributing characters of groundnut genotypes as influenced by different sources of sulphur, a field experiment was conducted at Koont Research Farm, PMAS-Arid Agriculture University, Chakwal during Kharif season 2013, located at latitude of 33.06° N, longitude 73.00° E, and 502 meters above sea level with annual rainfall of 650 - 850mm.The precipitation conditions prevailed during crop growth period is shown in Fig.1 and the soil physiochemical characteristics of experimental site are shown in table. 1.

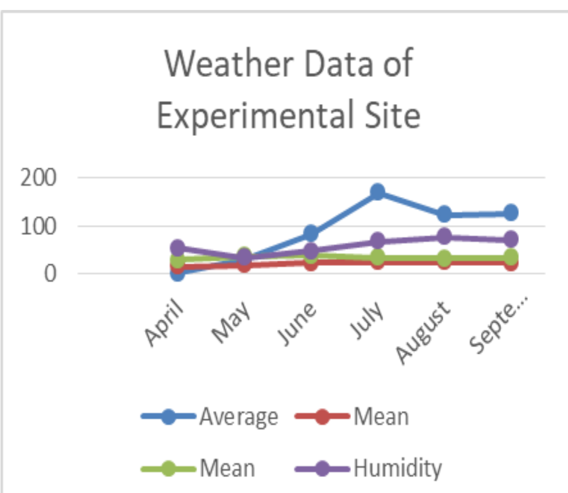

Figure 1: Precipitation data of the experimental site from April 2013 to September 2013

Soil analysis

Soil texture was determined by dispersion in sodium hexametaphosphate (Na $(PO_3)_6$) and density of suspension was recorded by hydrometer at specific time intervals (Gee and Bauder, 1982). Soil pH was determined using 1:2.5 suspension of soil in deionized water (Thomas and Hipp, 1996). Electrical conductivity was determined using 1:2.5 suspension of soil in deionized water. Then the EC of the supernatant liquid was measured at 25 ˚C using conductivity meter after standardization with 0.01 N KCl (Rhoades, 1996). Organic matter was determined through wet digestion method by using 1 N potassium dichromate solution and concentrated sulphuric acid and was titrated against 0.5 N ferrous ammonium sulphates (Nelson and Sommers., 1982). Cation exchange capacity was determined by using 1 M sodium acetate at pH 8.5 (Rhoades and Polemio., 1977). $CaCO_3$ content in the soil was determined using HCl and titration against 1 N NaOH to a faint pink color end point (Soltanpour and Workman, 1981).

Treatments and cultivation practices

Field research was laid out in randomized complete block design (split plot) with four replicates. Four groundnut genotypes viz. Bari-2011, Golden, Bard-92 and PG-1058 were tested. Nitrogen, P and K nutrient rates were maintained at the rate of 25, 80 and 25 kg per ha (S1=0). Whereas sulphur was applied @45kg/ha in the form of SSP, SOP and gypsum (S2, S3 and S4 respectively). Genotypes and sulphur fertilizers were kept in main and sub plots respectively. There were six rows in each subplot by keeping row to row distance 45 cm and plant to plant distance 15 cm after thinning. While, the size of main plot was 32.4 m^2 and subplot was 8.1 m^2. Seed rate was used @ 100 kg ha^{-1}.

Plant parameters recorded

At maturity data of crop yield and yield contributing characters viz. number of plants per unit area, number of pegs per plant, number of pods per plant, number of seeds per pod, 100 seed weight, biological yield, seed yield and harvest index were recorded. Seed quality parameters viz. oil content, protein content, fatty acid profile. Seed oil content was measured by NMR system, protein content was determined by Kjeldahl method and fatty acids were determined by Gas Chromatography.

Statistical analysis

Computer Statistical Program STATISTIX 8.1 was used to analyze the data. ANOVA technique was used to check the overall significance of data and least significant difference (LSD) test at 5% probability level was employed to compare the treatment's mean (Montgomery, 2001).

Results and Discussion

Impact of sulphur sources on yield and attributing characteristics

Genotypes Bari-2011 and PG-1058 produced maximum number of plants per meter square than in Golden which was statistically at par with Bard-92 (Table. 2). The significant variances among different genotypes are in line with findings of Subhendu *et al*., (2005) who reported that gypsum application @ 400 kg per hectare significantly increased number of plants m^{-2}. Das and Garnayak (1995) noticed maximum plant density when gypsum was applied @ 60 kg ha^{-1}.

Groundnut genotypes and different sources of sulphur showed statistically significant differences for number of pegs per plant (Table. 2). Maximum number of pegs per plant was recorded in Bari-2011 while the genotype PG-1058 produced minimum. These variations amongst the

Table 1: Physical and Chemical Properties of the Experimental Site.

	Before Sowing		After Harvest	
DEPTH	**00-15 cm**	**15-30 cm**	**00-15 cm**	**15-30 cm**
Texture	sandy clay loam	sandy clay loam	sandy clay loam	sandy clay loam
Saturation (%)	38	38	37	37
Soil pH	7.4	7.5	7.41	7.5
EC (dsm^{-1})	0.82	0.83	0.85	0.90
Organic Matter (%)	0.88	0.57	0.85	0.55
Available P (mg kg^{-1})	8.2	5.2	7.8	5.0
Available K (mg kg^{-1})	120	80	110	90
SO4-S (ppm)	16.24	17.51	19.44	18.62

Table 2: Effect of genotype and sulphur application on yield and yield components of groundnut during 2013.

Treatments	No of Plant m^{-2}	No.of pegsplant^{-1}	No.of podsplant^{-1}	No.of seed pod^{-1}	100 seed weight	Biological yield	Seed yield	Harvest index
				Genotypes (G)				
Bari-2011	7.09	96.62	85.16	1.92	74.76	8123.6	1178.6	12.99
Golden	6.28	91.17	76.62	1.68	74.44	7900.6	975.1	12.22
Bard-92	6.34	91.57	78.49	1.67	60.55	8181.6	864.0	10.62
Pg-1058	7.09	88.78	75.77	1.76	60.37	8186.5	880.6	10.73
LSD≤0.05	0.5	6.5	4.5	0.02	0.9	422.9	68.1	1.1
				Sulphur sources (kg ha^{-1})				
Control	5.75	76.35	59.46	1.62	64.70	6578.9	652.0	10.08
SSP (45 kg ha-1)	6.78	105.36	93.51	1.90	69.43	8635.6	1183.8	12.38
SOP (45 kg ha-1)	7.00	96.02	85.30	1.73	67.90	8464.7	1049.3	12.41
Gypsum (400 kg ha^{-1})	7.28	90.44	77.70	1.77	68.09	8713.1	1013.1	11.68
LSD≤0.05	0.6	7.2	6.54	0.03	1.0	381.3	51.8	0.9

were credited to the different response of the genotypes to the environmental circumstances like variation in temperature and rainfall prevailing during the crop period. Gypsum fertilizer produced the maximum number of plants m^{-2} followed by SSP and SOP whereas minimum numbers of plants were observed in control treatment. Genotypes and sources of sulphur interactive effect depicted that (Table. 3) Bari-2011 along with Gypsum application produced maximum number of plants per m^2 compared to Bari-2011 with control. Other interactive effects showed varied degree of differences. These results different genotypes might be due to particular genetic makeup of genotypes and their place of origin as well as environmental conditions. Among different sources of sulphur, SSP produced maximum number of pegs per plant. Whereas, the minimum number of pegs per plant were detected in control treatment (Table. 3). The genotype Bari-2011 produced maximum number of pegs where SSP was applied. While minimum pegs were recorded in same genotype (Bari-2011) with control treatment. These results are in line with the findings of Dutta *et al*. (2000) who reported significant increase in number of pegs per plant with the application of sulphur @ 60 kg ha^{-1}.

Genotypes and sources of sulphur revealed statistically significant differences for number of pods per plant (Table. 2). Maximum number of pods per plant was recorded in Bari-2011 while minimum was produced by PG-1058. Among sulphur sources maximum number of pods per plant was recorded in SSP while minimum was produced in control. Interactive effect of genotype and sulphur fertilizer showed significant variations (Table. 3). Bari-2011 using SSP produced maximum number of pods per plant whereas, minimum was observed in Bari-2011 with control. These results are in accordance with Kalaiyarasan *et al.,* (2002) who reported that application of sulphur @ 45 kg per hectare significantly increased the number of pods per plant of groundnut, while Jamal *et al*. (2006) reported significant increase in number of pods per plant with application of sulphur @ 20 kg ha^{-1}.

Table 3: Interactive effect of groundnut genotypes and sulphur fertilizers on growth and yield characters.

Genotype	Sources of Sulphur	No. of plant m^{-2}	No of pegs $plant^{-1}$	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	100-seed weight (g)	Biological weight (kg ha^{-1})	Seed yield (kg ha^{-1})	Harvest index (%)
Bard-2011	Control	5.0	65.3	53.1	1.6	72.9	6409	715.5	12.6
	SSP	7.4	127.5	116.5	2.4	78.4	9188	1484.8	11.0
	SOP	6.8	97.5	86.4	1.9	74.0	8829	1279.5	14.6
	Gypsum	9.3	96.3	84.7	1.8	73.8	9003	1234.5	13.8
Golden	Control	6.0	81.8	61.2	1.6	67.9	7071	600.3	9.4
	SSP	5.9	102.0	89.6	1.7	77.8	8428	1270.3	15.1
	SOP	6.9	92.9	83.9	1.6	75.4	8424	1107.8	13.3
	Gypsum	6.4	87.9	71.8	1.8	76.7	8341	922.3	11.1
Bard	Control	6.3	84.5	64.4	1.7	59.3	7129	624.3	8.9
	SSP	6.5	95.6	82.6	1.7	60.9	8401	917.3	10.9
	SOP	7.1	97.0	87.9	1.6	61.3	8419	891.8	10.6
	Gypsum	5.5	89.2	78.9	1.7	61.0	8604	1022.8	12.1
PG-1058	Control	5.6	73.5	59.1	1.7	58.8	7129	668	9.4
	SSP	7.3	96.3	85.3	1.8	60.9	8525	1063	12.5
	SOP	7.2	96.7	83.1	1.8	60.9	8188	918.3	11.2
	Gypsum	8.0	88.3	75.5	1.8	60.9	8905	873	9.8
	LSD (5%)	1.30	14.43	13.08	0.06	2.00	762.6	103.1	1.90

Statistically significant variations were found among the groundnut genotypes, sources of sulphur and their interaction for number of seeds per pod. Among genotypes maximum number of seeds per pod were recorded in Bari-2011 while Bard-92 attained minimum number of seeds which was statistically at par with Golden. Genetic response and prevailing environmental status might be the reason for variations found among genotypes for number of seeds per pod. In view the various sources of sulphur, SSP produced maximum number of seeds per pod whereas minimum number of seeds per pod were observed in control. Interactive effect of Bari-2011 and SSP fertilizer produced maximum number of seeds per pod while minimum was recorded in Golden with control treatment. These results are in accordance with findings of Jamal *et al*. (2006). They found significant increase in number of seed pod^{-1} with application of sulphur @ 20 kg ha^{-1}. Similarly, Singh (2007) who used different levels of sulphur 0, 45 and 80 kg per hectare and reported S @ 45 kg per hectare produced higher number of seeds per pod. Kumaran (2001) also reported that sulphur @ 400 kg per hectare produced maximum number of seeds per pod.

Seed weight directly and positively influence the yield of crop. Groundnut genotypes, sulphur fertilizers and their interaction (Table. 2 & 3) exhibited statistically significant differences for hundred seed weight (seed index). Lowest seed index was documented in Bari-2011 while highest 100 seed weight was recorded in PG-1058 which was statistically same with Bard-92. Genetic formations of genotypes of different origin and environmental factors during crop period might be responsible for variation of genotypes for this trait. Among different sulphur fertilizers maximum 100-seed weight was recorded by SSP whereas, control treatment gained minimum seed index. In cultivar into sulphur interaction, Bari-2011 beside the application of SSP fertilizer attained highest seed index whereas, lowest 100-seed weight was recorded in PG-1058 with control.

These results are in line with the findings of Jamal *et al*. (2006) who reported significant increase in 100-seed weight with application of sulphur @ 20 kg per hectare.

Genotypes showed statistically non-significant differences for biological yield but the sulphur fertilizers and their interaction with genotypes were statistically significant (Table. 2 and 3). Among sulphur sources, highest biomass production was produced by gypsum which was statistically similar with SSP and SOP, whereas, control produced the lowest biological yield. Interaction revealed that Bari-2011 along with SSP produced maximum biological yield and the same genotype produced minimum biological yield in control treatment. It is inferred that Bari-2011 is greatly influenced by sulphur fertilizer (SSP). Prasad, (2003) also reported significant increase in biological yield when sulphur was applied @ 40 kg ha^{-1}.

Genotypes and sulphur fertilizers revealed statistically significant impact for seed yield. Maximum seed yield was produced by Bari-2011 while minimum was recorded in Bard-92 followed by PG-1058. Genetic diversity of genotypes, their origins and environmental conditions directly influence the growth characters which directly

Table 4: Effect of genotype and sulphur application on oil content and quality of groundnut.

Treatments	Oil Content	Protein Content	Palmitic acid	Stearic acid	Linolenic acid	Oleic acid
Genotypes (G)						
Bari-2011	52.9	27.8	8.7	4.2	31.4	45.8
Golden	52.5	27.6	8.6	4.2	31.5	42.5
Bard-92	51.8	27.5	8.3	4.0	30.4	43.1
PG-1058	50.9	27.2	8.5	3.8	31.2	47.2
LSD≤0.05	1.3	0.8	0.3	0.3	0.04	2.7
Sulphur sources (kg ha^{-1})						
Control	52.3	26.2	7.3	3.5	27.8	39.4
SSP (45 kg ha^{-1})	52.6	28.5	9.0	4.3	32.4	45.1
SOP (45 kg ha^{-1})	53.1	27.6	8.9	4.2	32.3	47.5
Gypsum (400 kg ha^{-1})	50.1	27.7	8.8	4.2	32.0	46.6
LSD≤0.05	1.3	0.7	0.5	0.3	0.3	2.1

Table 5: Interactive effect of groundnut genotypes and sulphur fertilizers on oil content and quality of groundnut

Genotype	Sources of Sulphur	Oil Content	Protein Content	Palmitic acid	Stearic acid	Linolenic acid	Oleic acid
Bard-2011	**Control**	53.2	26.1	7.8	3.8	28.4	42.4
	SSP	52.8	28.4	9.0	4.5	32.1	44.1
	SOP	54.3	28.1	8.7	4.3	33.7	49.3
	Gypsum	52.2	28.6	9.2	4.3	31.4	47.5
Golden	**Control**	51.6	26.8	7.1	3.4	27.8	37.6
	SSP	53.2	28.2	9.2	4.6	33.3	42.5
	SOP	52.6	27.9	9.2	4.4	31.5	47.6
	Gypsum	49.8	27.4	8.8	4.4	33.3	42.2
Bard	**Control**	50.9	26.1	7.1	3.4	27.8	37.4
	SSP	51.2	28.5	8.7	4.4	31.7	43.6
	SOP	52.7	27.9	8.8	4.1	31.5	43.2
	Gypsum	48.9	27.4	8.7	4.3	30.7	48.4
PG-1058	**Control**	53.5	26.0	7.3	3.4	27.4	40.3
	SSP	53.1	28.7	9.3	3.8	32.5	50.2
	SOP	52.9	29.4	8.9	3.9	32.4	49.9
	Gypsum	50.6	27.7	8.5	4.1	32.7	48.5
	LSD (5%)	2.6	1.5	0.9	0.5	0.5	4.3

influence the final yield. Among sources of sulphur, SSP produced maximum seed yield, however, minimum yield was recorded in control. Bari-2011 x SSP produced maximum seed yield while minimum seed yield was observed in Golden by control treatment. These results are in accordance with Nabi *et al*., (1999) who reported that SSP applied @ 45 kg per hectare produced highest seed yield. Similarly, Jamal *et al*. (2006) reported significant increase in seed yield with application of sulphur @ 20 kg ha^{-1}.

Statistically significant differences were found among the genotypes, sources of sulphur and their interaction (Table. 2 and 3). Bari-2011 produced highest harvest H.I. index while lowest harvest index value was recorded in Bard-92. Maximum harvest index was obtained by SOP fertilizer which was statistically at par with SSP and gypsum while minimum H.I. was recorded in control. Genotype Golden with SSP produced maximum harvest index while minimum H.I. was observed in Bard-92 with control treatment. Jamal *et al*., (2010) concluded that H.I was significantly enhanced when sulphur was applied @ 20 kg per hectare.

According to Tabatabaei (1986), the sulfur increases seed yield and plant nutrition because it improves the soil reaction that causes an increase in the absorbable phosphorous of the soil. Similar work has also been reported by Sarkar *et al*. (2002). Ishag (1992) and Abd El-Hady (2007) mentioned that foliar application of micronutrients increases the concentrations of macro and micronutrients in peanuts seeds and this occurs because of the vital physiological roles in plant cells that improve the uptake of plant nutrients.

Impact of sulphur sources on seed quality

Among genotypes (Table 4) Bari-2011 accumulated maximum oil content followed by PG-1058 and Golden. Whereas, minimum oil content was recorded in Bard-92 which was statistically at par with Golden. Sources of sulphur showed statistically non-significant differences for oil content while interactive effect of genotypes x sources of sulphur showed statistically significant differences for oil content accumulation (Table 5). Maximum oil content were accumulated in Bari-2011 x SOP whereas, minimum were observed in the Bard-92 x gypsum.

Genotypes (Table 4) showed statistically non-significant differences for protein content while among sulphur sources maximum protein content were accumulated in SSP followed by gypsum whereas, minimum protein content were recorded in control. The interactive effect of genotypes x sources (Table 5) of sulphur showed statistically significant difference for protein content accumulation. PG-1058 x SSP produced maximum protein content. Whereas, minimum protein assimilation was recorded in PG-1058 x control. These results are in accordance with findings of Jamal *et al*., (2006) who reported significant increase in protein content with application of sulphur @ 20 kg per ha. In the same way, these results are in accordance with findings of Tathe *et al.*, (2008). They reported significant increase in protein content with application of sulphur @ 120 kg ha^{-1}.

Among groundnut genotypes (Table 4) Bari-2011 accumulated maximum palmitic acid content followed Golden and PG-1058 while minimum palmitic acid content was recorded in Bard-92. Sources of sulphur also depicted significant response for palmitic acid. SSP accumulated maximum palmitic acid content accumulation while minimum was recorded in control. Bari-2011 x gypsum (Table 5) produced maximum palmitic acid content whereas minimum was recorded in PG-1058 x control. Other interactive effects showed varied degree of difference. These results are in line with the findings of Jaggi (1994) who used different sources and levels of sulphur and found significant increase in amino acid content with the application of sulphur @ 60 kg ha^{-1}.

Among genotypes (Table 4) Bari-2011 accumulated maximum stearic acid content followed by PG-1058 while minimum stearic acid content was recorded in Bard-92. Among sources of sulphur SSP accumulated maximum stearic acid followed by SOP and gypsum while minimum stearic acid content was recorded in control. The interactive effect of genotypes x sources of sulphur also showed statistically significant difference for stearic acid accumulation. Golden x SSP (Table 5) produced maximum stearic acid content while minimum stearic acid accumulation was recorded in PG-1058 x control. These results are in line with the findings of Jaggi (1994) who used different sources and levels of sulphur and found significant increase in amino acid content with the application of sulphur @ 60 kg through SSP.

Genotypes (Table 4) showed statistically non-significant differences for linolenic acid content. Among sulphur sources, maximum linolenic acid content accumulation was recorded in SSP followed by SOP and gypsum, whereas, minimum was recorded in control. The interactive effect of genotypes x sources of sulphur (Table 5) showed statistically significant difference for linolenic acid content. Golden x gypsum produced maximum linolenic acid content whereas, minimum linolenic acid assimilation was recorded in PG-1058 x control. These results are in line with the findings of Jaggi (1994) who used different sources and levels of sulphur and found significant increase in amino acid content with the application of sulphur @ 60 kg ha^{-1}.

Among genotypes (Table 4) maximum oleic acid was accumulated in PG-1058 which was statistically at par with Bari-2011 while minimum was recorded in Bard-92 followed by Golden. Sources of sulphur also depicted a significant response for oleic acid content. SOP accumulated maximum oleic acid content followed by gypsum. Whereas, minimum oleic acid content was recorded in control. PG-1058 x SSP (Table 5) produced maximum oleic acid content while minimum oleic acid was accumulated in Bard-92 x control. These results are in line with Jaggi (1994) who uses different sources and levels of sulphur and found significant increase in amino acid content with the application of sulphur @ 60 kg through SSP.

Conclusion

It is concluded from present study that sulphur sources had significant positive effects on yield and yield related parameters of groundnut genotypes. However, the oil content was unaffected. Among genotypes Bari-2011 produced maximum yield and oil content.

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