Research Article

Response of Sesame (*Sesamum indicum* L.) to Sowing Methods, Nitrogen and Sulphur Levels

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Abstract | Water shortage should be intimidating issue for agriculture crops. Adaptation of modern techniques and management practices in oil seed crops can reduce water shortage risks with optimum yield in oil seed crops. Sesame is being considered the most tolerant crop for avoiding drought conditions with higher yield. Experiments on "response of sesame to sowing methods, nitrogen and sulphur levels" were carried out in Agronomy Research Farms, The University of Agriculture, Peshawar. During two consecutive Kharif growing seasons of 2013 and 2014, respectively. Three sowing methods (flat, ridges and raised bed) were kept as main plot factor, whereas four nitrogen levels (00, 60, 120, and 180 kg ha^{-1}) and four treatments of sulphur (00, 20, 30 and 40 kg ha^{-1}), were kept as sub plot factors, which were replicated four time for each experiment. Urea and ammonium sulphate fertilizers were used as a source of nitrogen and sulfur nutrients. Results showed that all quantitative and qualitative parameters of sesame had significantly influenced by year. Study showed that raised bed sown plots significantly ($p \leq 0.05$) produced more: leaves plant^{-1} (243), leaves area plant^{-1}(444.35cm^2), branchesplant^{-1}(9), plant height (198.51cm), and seed yield (1339kg ha^{-1}), were recorded as compared with other sowing methods. It was also resulted from findings that N (180 kg ha^{-1}) had significantly delayed flower and pod formation (7 and 9days) respectively as compared with control plots. Higher: leaves plant^{-1} (242), leaves area plant^{-1}(492.79cm^2), branches plant^{-1} (9), plant height (212.56cm), and seed yield (1581kg ha^{-1}). Sulphur applied at 40 kg S ha^{-1} had significantly produced more: leaves area plant^{-1}(446.14cm^2), plant height (192.25cm), and seed yield (1346kg ha^{-1}), as compared with lower levels of sulphur. Interactive response of NxS and NxSxSM, were found significant for leaves area plant^{-1}, plant height and seed yield. It is concluded that sowing sesame on raised bed and followed by ridges sowing method, with combined application of 180 kg N ha^{-1} and 40 kg S ha^{-1} produced higher yield and yield related components.

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Introduction

Sesame (*Sesamum indicum* L.) is an important oil seed crop of family pedaliaceae. It is an annual short day plant, having unicullum or multi-branches, depending on variety, and gets a height 1-2 m. (Ashri, 2010). Sesame seed contains (46-64 %) oil seed content, (20 to 28%) protein, (14 to 16%) sugar and (5-7%) minerals (Toan *et al.*, 2010). Archeological report mentioned 2750 years ago that sesame seed were pressed manually to extract oil for different purposes, in Urartu region (SESACO, 2014). Total

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area under cultivation of sesame in Pakistan during (2014-15) was 85000 hec, with total production of 35000 tons with an average yield of 405 kg ha^{-1}. Total sesame production 0.04 (000 tonnes), with average yield of Khyber Pakhtunkhwa was recorded 1000 kg ha^{-1}, which is higher than the national average yield 405 kg ha^{-1} (DSK, 2017; MINFA, 2015-16). In 2010, Sesame seed world widely harvested about (3.84 million metric tons. Burma was the leading sesame producing country in terms of sesame seed in (2013-14), where India and China were leading in total production.

Sesame is being considered the most drought resistant vegetable oil crop due to its extensive root system. It has surviving adoptability features in drought climatic conditions, but in same time it also requires optimum moisture for good germination and initial seedling stands. Humidity in rainy seasons offers different fungal diseases in summer seasons (Ray, 2008). It antioxidant properties makes sesame oil the most stable, with long and better shelf life, which are considered more effective in cardio-vascular, hyper-cholesterolemia, hypertension, cancer diseases and immune system disorders (Kamal-Eldin *et al*., 2011; Cheung *et al*., 2007).

Sowing methods make ensure good plants establishment and later on development process. Sesame sown on ridges and raised bed has better moisture availability and retention strategies than flat sowing method (SESACO, 2014). Sesame sown on raised and ridges produced greater: capsules $plant^{-1}$, seed weight $plant^{-1}$ and 1000-seed weight as compared with flat and furrow sowing methods (Malik *et al*., 2003). Ridge sowing method is more effective to overcome wilting, lodging, leaf spot, and stem blight diseases than flat planting pattern. Cost benefit ratio of ridge planting was higher 1:2.86, than flat sown crops. Daremcar Annual Report (2006-2007), mentioned that raised bed had significantly increased the cotton yield by 2.4% ha^{-1} as compared with flat sowing.

Food security including edible oil production has been top on the main issue list and has been in focused of the agriculture scientist, researcher and a common man. To overcome this issue crops should produce through newly released variety with modern cropping management and inorganic management practices. Significant increase was recorded in sesame yield and yield related components with increase in nitrogen levels. Heavier seed was taken from 120 kg N ha^{-1} (Hasanapour *et al*., 2012), where higher capsules and seed weight $plant^{-1}$ was increased from 0 to 80 kg N ha^{-1} (Deshmukh *et al*., 1990). Nitrogen at 120 kg N ha^{-1} had enhance seed oil content (53.69%), seed protein content (23.46%), and oil yield (1630 kg ha^{-1} (Ramakrishnan *et al*., 1994). Yield and yield related parameters were significantly varied up to 150 N kg ha^{-1} (El-Nakhlawy and Shaheen, 2009). All yield attributes were promoted except oil seed content upto 205 kg N ha^{-1} (Asl, 2017; El-Nakhlawy and Shaheen, 2009).

Sulphur has a significant role in oil seed crops growth, and development and is considered the 4th major macro nutrient for plant growth and development (Jamal *et al*., 2009). Sulphur plays a vital role in protein synthesis: methionine (21%S) and cysteine (27%S). Sulphur enhanced biochemical process in plant tissues which effect yield production up to 20 kg S ha^{-1} (Mondal *et al*., 2012). Higher yield responses were recorded up to 30 kg S ha^{-1}. Sulphur improved qualitative and quantitative parameters up to 60 kg S ha^{-1} (Mondal *et al*., 2012; Raja *et al*., 2007b). Growth and yield of sesame enhanced with combined application of nitrogen and sulphur. Synergetic effect was found between nitrogen and sulphur nutrients (Jamal *et al*., 2009). N and S availability and uptake efficiency enhanced in the presence of both nitrogen and sulphur nutrients in soil (Shilpi *et al*., 2014). Mansoori (2012) reported that yield and oil seed content increased with application of N (120 kg ha^{-1}) and S (40 kg S ha^{-1}). Oil seed content increased with combined application of 60 kg N ha^{-1} and 40 kg S ha^{-1} (Shilpi *et al*., 2014).

The importance of sesame crop for seed and oil production, food industry, health concern, and economic profitability, these experiments were carried out find out the best sowing methods, nitrogen and sulphur levels for higher yield of sesame at the limited irrigated agro-climatic conditions of Peshawar-valley.

Materials and Methods

Field trails on the response of sesame to sowing methods, nitrogen and sulphur levels, were designed and completed at Agronomy Research farms (ARF), at The University of Agriculture, Peshawar- Pakistan, during kharif season on June 30th of 2013 and 2014. Each experiment was designed in randomized complete block (RCB), with split plot arrangement, having three sowing methods (flat, ridge 50 and raised bed sowing methods) in main plots, three nitrogen rates (60, 120 and 180 kg ha^{-1}) and three sulphur levels (20, 30 and 40 kg ha^{-1}) were in sub main plot factor, having one control for both N and S, were replicated four time. Urea (split dose 50 % after 1st irrigation on 20th July and 50 % at 2nd irrigation on 5th August on both years) and ammonium sulphate (whole at sowing time on 30th June) was used as fertilizer source for N and S. Each subplot size of 4m x 4m, rows were separated by 50 cm, and intra plant space was maintained 10 cm in each experiment. Variety SG-30, sown at the rate of 6 kg ha^{-1}. Being less dimension of sub plot 4x4, ridges (50cm ridge to ridge distance /20 cm height) and raised bed (50 cm raised bed to raised bed distance /20 cm height of the raised bed /20 cm p-p distance) were made manually as well as with help of machinery where it was possible. Experimental soil was sandy loamy, strongly calcareous and alkaline in reaction with pH (8.1), EC (0.28 dS m^{-1}), total nitrogen (0.05 %) and was marginal in AB-DTPA extractable K (107 mg kg^{-1}). Weeding, irrigation, pesticides, herbicides, activities were carried out uniformly for all the experimental units throughout the growing Kharif seasons of 2013 and 2014. Data were recorded on days to 1st flower and pod formation, leaves, leaves area and branches $plant^{-1}$, plant height (cm), and seed yield (kg ha^{-1}).

Days to first flower and pod formation

Data on days to first flower and capsule formation of sesame crop between flower, pod formation and date of sowing were 1st observed and recorded in each subplot of sesame.

Leaves plant^{-1}

Five randomly plants in each subplot were 1st collected and leaves were counted, and its average was taken as leaves $plant^{-1}$.

Leaves area plant^{-1}

Five plantsat three different rows per plot were tagged and leaves areas were measured twice once at 35 days after sowing and then 65 days after sowing with the help of (C1-202, Portable Leaf Area Meter USA).

Branches plant^{-1}

After harvesting ten randomly plants were collected from each sup plot of sesame and counted for branches and averaged for branches $plant^{-1}$.

Plant height (cm)

Plant height (cm) was taken in ten selected plants with help of measuring rode from top to bottom ground level.

Seed yield (kg ha^{-1})

After threshing of four central rows in each subplot of sesame crop, seed were weighted with an electronic balance and were converted into kg ha^{-1}.

Data analysis

Different statistical tools were used to analyze and mean differences between treatments were compared for RCB design by LSD at 5% level of probability, when the F- values was significant (Jan *et al*., 2009). Graphs were made with Sigma plot software (12).

Results and Discussion

Days to 1st flowering

Flowering formation had had significantly affected by nitrogen and year (Table 1). As plot fertilized with 60 and 120 kg N ha^{-1} had initiated early flowering, while late flowering was recorded in 180 N kg ha^{-1}. Late flower formation in sesame might be due to high nitrogen and sulphur application which produce vigorous plant growth, resulted in delay flowering. Flowering delayed with increasing nitrogen and sulphur from lower to higher levels (Haruna, 2011). In year 2013, earlier flowers were produced as compared to year 2014. Delayed flowering in year 2014 might be high utilization of nutrients in the presence of nitrogen and sulphur, which prolongs vegetative growth stage. These finding are supported by (Bareja, 2011), who mentioned that soil and weather conditions can change plant growth stages (flowering stage). Significantly delay in 1stflower formation was recorded in fertilized plots as compared with control plots. Interactions between year (Y) x nitrogen (N), was found significant for flower formation. Higher nitrogen application can boost vegetative growth, which resulted in late flower formation by (Raja *et al*., 2007).

Days to 1st pod formation

Pod formation duration had significantly affected by nitrogen (Table 2). Year (as a factor) had also significantly influenced days to pod formation. Significantly delayed pods were produced, when sesame was fertilized with 180 N kg ha^{-1}, as compared with other nitrogen levels. These changes in pod formation linked with different nitrogen levels application. Higher nitrogen application in sesame may boost vegetative growth with delayed pod formation process. Haruna (2011) and El-Nakhlawy and Shaheen (2009) reported that delay in pod formation was recorded with increasing level of N supply from 0 to 200 kg ha^{-1}. These changes in days to pod formation might be due to different weather and soil conditions of the experimental site in two consecutive years of the study. Different weather, soil moisture and nutrients bring variations in plant growth and development (Bareja, 2011). Significantly earlier 1[st]pod formation n control plots, whereas delayed pods were recorded in fertilized plot.

Table 1: *Days to 1[st] flower formation of sesame as affected by sowing methods, nitrogen and sulfur levels during year 2013, and 2014.*

Sowing methods	**2013**	**2014**	**Mean**
Ridge	45	46	46
Flat bed	45	46	46
Raised bed	45	47	46
LSD $_{(0.05)}$			ns
Nitrogen (kg ha^{-1})			
60	44	46	45 b
120	44	46	45 b
180	46	48	47 a
LSD$_{(0.05)}$			1
Sulphur (kg ha^{-1})			
20	46	46	46
30	45	47	46
40	45	47	46
LSD$_{(0.05)}$			ns
Year	45	47	*
Planned mean comparison			
Control	39	41	40
Rest	45	47	46
Significance			*
Interactions			
Y × SM	ns	SM × S	ns
N × S	ns	SM × N × S	ns
Y × N	*	Y × SM × N	ns
Y × S	ns	Y × SM × S	ns
Y × N × S	ns	Y × SM × N × S	ns
SM × N	ns		

*Mean followed different letters are statistically different from each at 5 % of probability; *: indicate significance at 5 % level of probability; ns: indicates not significant.*

Table 2: *Days to 1[st] pod formation of sesame as affected by sowing methods, nitrogen and sulfur levels during year 2013, and 2014.*

Sowing methods	**2013**	**2014**	**Mean**
Ridge	52	54	53
Flat bed	52	54	53
Raised bed	53	54	54
LSD$_{(0.05)}$			ns
Nitrogen (kg ha^{-1})			
60	52	54	53 b
120	52	54	53 b
180	55	56	55 a
LSD$_{(0.05)}$			1
Sulphur (kg ha^{-1})			
20	54	53	54
30	53	54	54
40	53	54	54
LSD $_{(0.05)}$			ns
Year	53	54	*
Planned mean comparison			
Control	47	45	46
Rest	53	54	54
Significance			*
Interactions			
Y × SM	ns	SM × S	ns
N × S	ns	SM × N × S	ns
Y × N	*	Y × SM × N	ns
Y × S	ns	Y × SM × S	ns
Y × N × S	ns	Y×SM×N×S	ns
SM × N	ns		

*Mean followed different letters are statistically different from each at 5 % of probability; *: indicate significance at 5 % level of probability; ns: indicates not significant.*

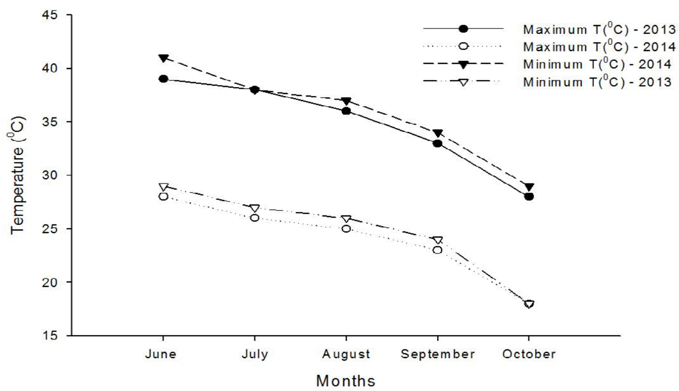

Figure 1: *Monthly maximum and minimum temperature (⁰C) data during sesame growing season of year 2013 and 2014 at experimental site.*

Leaves plant^{-1}

Table 3, presents data on number of leaves plant^{-1}.

Significantly higher number of leaves were produced by raised bed sowing method as compared with other sowing methods. Significantly more leaves plant^{-1} were produced with 180 kg N ha^{-1} whereas, lower number of leaves plant $^{-1}$ were produced when plots applied at 60 kg N ha^{-1}. Fertilized plots had produced more leaves plant^{-1}as compared with control plots. Higher number leaves plant^{-1} were noted in year 2014. Variation in number of leaves might be due to maximum utilization of nitrogen nutrient for higher plant growth and development in different soil conditions. Leaves were increased up to 205 kg N ha^{-1} (El-Nakhlawy and Shaheen, 2009). Interaction between SM × N, given in Figure 3, and was found significant for leaves plant^{-1}. Nitrogen fertilization significantly encouraged leaves plant^{-1}in each sowing method. These variations in leaves could be considered

Table 3: *Leaves plant^{-1} of sesame as affected by sowing methods, nitrogen and sulfur levels during year 2013 and 2014.*

Sowing methods	**2013**	**2014**	**Mean**
Ridge	208	218	213 b
Flat	183	187	185 c
Raised bed	241	245	243 a
$LSD_{(0.05)}$			4
Nitrogen (kg ha^{-1})			
60	184	192	188 c
120	206	214	210 b
180	241	245	243 a
$LSD_{(0.05)}$			2
Sulphur (kg ha^{-1})			
20	211	215	213
30	211	217	214
40	212	216	214
$LSD_{(0.05)}$			ns
Year	210	215	*
Planned mean comparison			
Control	133	143	138
Rest	210	217	214
Significance			*
Interactions			
Y × SM	ns	SM × S	ns
N × S	ns	SM × N × S	ns
Y × N	ns	Y × SM × N	*
Y × S	ns	Y×SM×S	ns
Y × N × S	ns	Y×SM×N×S	ns
SM × N	*		

*Mean followed different letters are statistically different from each at 5 % of probability; *: indicate significance at 5 % level of probability; ns: indicates not significant.*

due to well fertile and aerated soil with optimum utilization of nutrients for plant growth. Malik *et al.* (2003), also reported similar results that raised bed sown plots provide more nutrients for plant growth and development.

Leaves area plant^{-1}

Sowing methods had significantly produced higher leaf area plant $^{-1}$ (444.35 cm^2), in raised seed bed, while lower leaves area plant^{-1} (428.67 cm^2) was recorded in flat sown plots (Table 4). Higher leaves area plant^{-1} were measured from plots treated with 180 kg N ha^{-1}, as compared with other nitrogen levels. Sulphur at 40 kg S ha^{-1} had significantly produced maximum leaves area plant^{-1} as compare to others sulphur levels. Control vs rest analysis of data showed that lower leaves area plant^{-1} was recorded in control plots, where fertilized sesame plots produced higher leaves area plant^{-1}. More leaves area plant^{-1}of sesame was recorded in year 2014, as compared with year 2013.Leaves areas difference with each factor could be considered increased in total photosynthates for maximum growth with optimum utilization of available nutrients. Higher nitrogen application increased number of leaves (Younis *et al.*, 2020). Figure 4, shows that (N) and (S) combined application enhanced crop growth and development which indirectly promoted leaves parameters. Similarly, interactions between (SM × N) Figure 5, (SM × N × S) Figure 6, and (Y × SM × S) were found highly significant for leaves plant^{-1}. Figure 7, shows that leaves area plant^{-1} has increased in each sowing method with increasing in nitrogen and sulphur fertilizer levels from lower to higher application. Nitrogen and sulphur application promoted leaf related parameter (Raja *et al.*, 2007).

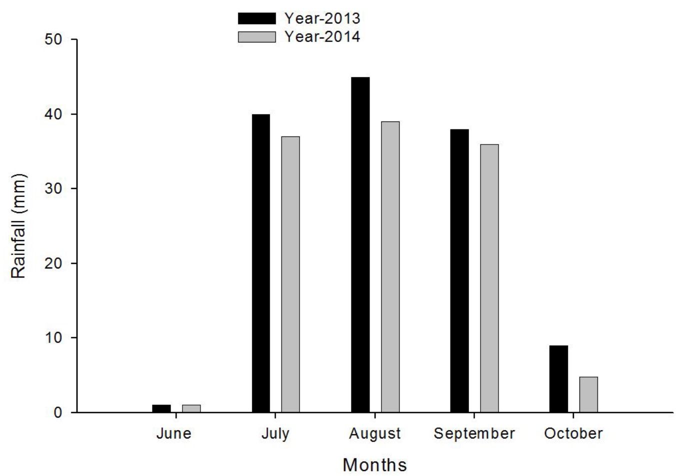

Figure 2: *Monthly rainfall (mm) data during sesame growing season of 2013 and 2014 (June to October) at experimental site.*

Table 4: *Leaves area plant^{-1} (cm^2) of sesame as affected by sowing methods, nitrogen and sulfur levels during year 2013 and 2014.*

Sowing methods	**2013**	**2014**	**Mean**
Ridge	437.61	441.36	439.49 b
Flat	426.28	431.06	428.67 c
Raised bed	441.58	447.11	444.35 a
LSD $_{(0.05)}$			3.0
Nitrogen (kg ha^{-1})			
60	391.64	395.97	393.81 c
120	423.44	428.44	425.90 b
180	490.39	495.19	492.79 a
LSD $_{(0.05)}$			1.0
Sulphur (kg ha^{-1})			
20	427.22	430.69	428.96 c
30	434.81	440.00	437.40 b
40	443.44	448.83	446.14 a
LSD $_{(0.05)}$			1.0
Year	435.16	439.84	*
Planned mean comparison			
Control	335.42	340.42	337.92
Rest	435.16	439.84	437.50
Significance			*
Interactions			
Y × SM	ns	SM × S	ns
N × S	*	SM × N × S	*
Y × N	ns	Y × SM × N	ns
Y × S	ns	Y × SM × S	*
Y × N × S	ns	Y×SM×N×S	ns
SM × N	*		

*Mean followed different letters are statistically different from each at 5 % of probability; *: indicate significance at 5 % level of probability; ns: indicates not significant.*

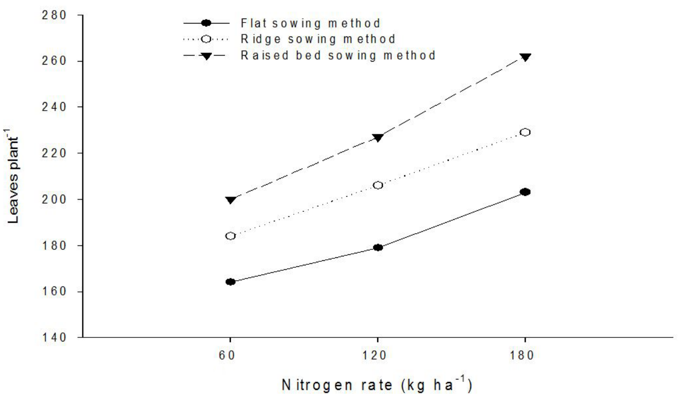

Figure 3: *Interaction between (NxSM) for days to 1eave plant^{-1} of sesame.*

Branches plant^{-1}

Data regarding branches plant^{-1} are shown in Table 5. Higher number of branches plant^{-1}were produced in raised seed bed and ridges sown plots, respectively, while minimum branches plant^{-1} of were produced in flat sown plots N (180 kg ha^{-1}) had significantly produced higher number of branches plant^{-1}, as compared with other levels. Fertilized plots had significantly produced more number of branches plant^{-1}, as compared to control plots. Higher branches plant^{-1} were recorded in 2nd year of the study. Well

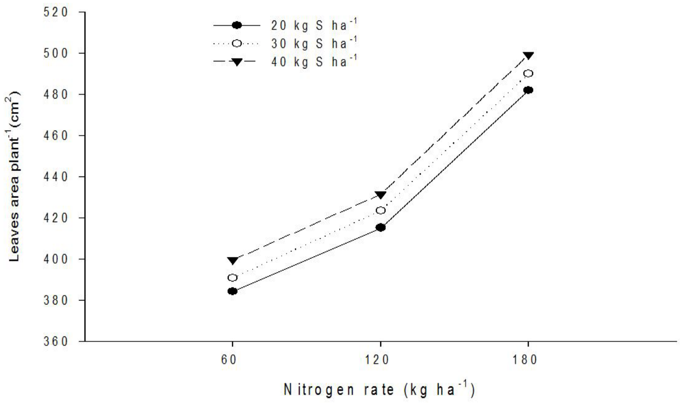

Figure 4: *Interaction between (SxN) fertilizers for leaves area plant^{-1} of sesame.*

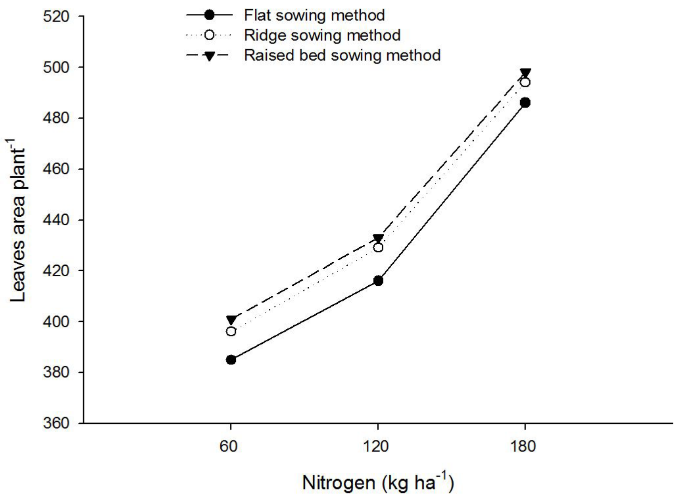

Figure 5: *Interaction between nitrogen and sowing methods for leaves area plant^{-1}.*

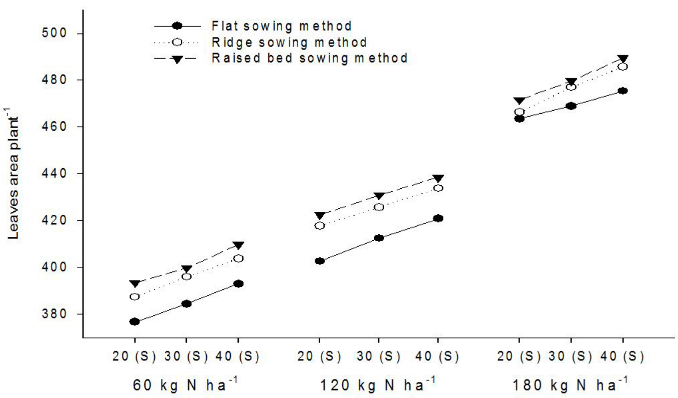

Figure 6: *Interaction between sowing methods, nitrogen and sulfur fertilizers leave area plant^{-1} of sesam.*

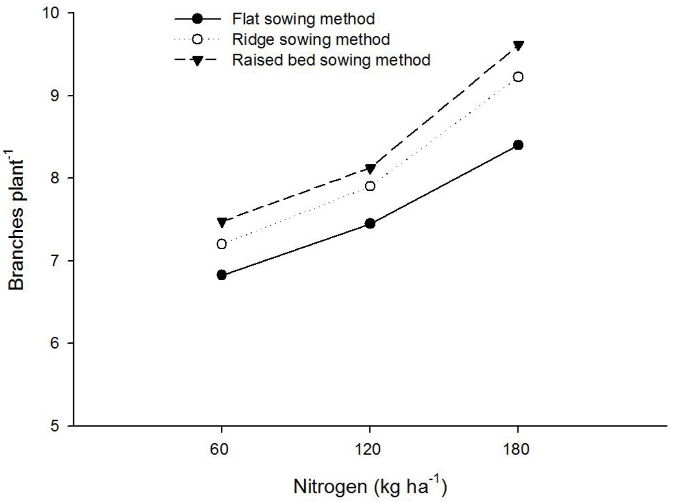

Figure 7: *Interaction between (NxS) fertilizers for branches plant^{-1} of sesame.*

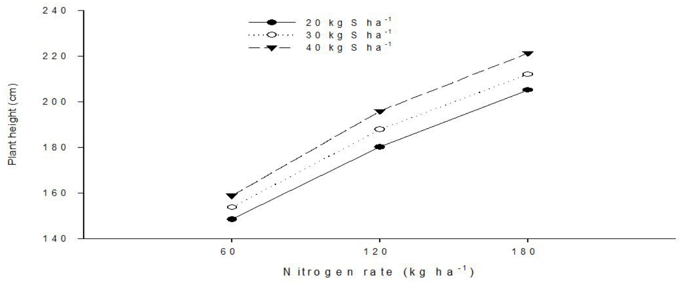

Figure 8: *Interaction between nitrogen and sulphur fertilizers for plant height of sesame.*

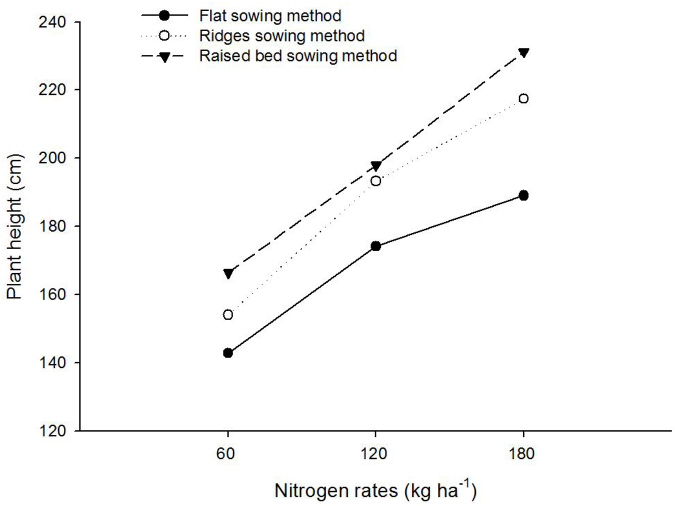

Figure 9: *Interaction between nitrogen and sowing methods for plant height of sesame.*

aerated soil structure of raised bed, retained more water and nutrients for maximum growth (Haurna, 2011). Interaction between SM × N (Figure 9) shows that branches in raised and ridge sowing method had significantly responded with increase in nitrogen levels.

Plant height (cm)

Table 6, shows data concerning plant height of sesame. Mean comparison values of plant height data showed that different sowing methods, nitrogen and sulfur levels had varied ($p<0.05$), plant height, whereas combine year variations had significantly changed in sesame plant height. Taller plants were measured from plots sown on raised bed, as compared with other sowing methods, whereas nitrogen and sulfur significantly produced taller plants at 180 kg ha^{-1}and 40 kg Sha^{-1}, respectively. Variation in plant height of raised bed with nitrogen and sulphur application might be due favorable condition for root growth with optimum nutrients utilization in loose and fertile raised bed soil. Purushottam (2005) observed significant increase in plant height with increasing in each increment in nitrogen fertilizer from 50 to 205

Table 5: *Branches plant^{-1} of sesame as affected by sowing methods, nitrogen and sulfur levels during 2013 and 2014.*

Sowing methods	**2013**	**2014**	**Mean**
Flat	8	9	9 a
Ridge	7	8	8 b
Raised bed	8	9	9 a
LSD $_{(0.05)}$			1
Nitrogen (kg ha^{-1})			
60	7	8	7 c
120	8	9	8 b
180	9	10	9 a
LSD $_{(0.05)}$			1
Sulphur (kg ha^{-1})			
20	8	9	8
30	9	8	8
40	8	9	8
LSD $_{(0.05)}$			ns
Year	8	9	*
Planned mean comparison			
Control	5	5	5
Rest	8	9	8
Significance			*
Interactions			
Y × SM	ns	SM × S	ns
N × S	ns	SM × N × S	ns
Y × N	ns	Y × SM × N	ns
Y × S	ns	Y × SM × S	ns
Y × N × S	ns	Y×SM×N×S	ns
SM × N	*		

*Mean followed different letters are statistically different from each at 5 % of probability; *: indicate significance at 5 % level of probability; ns: indicates not significant.*

Table 6: *Plant height (cm) of sesame as affected by sowing methods, nitrogen and sulfur levels during year 2013 and 2014.*

Sowing methods	2013	2014	Mean
Ridge	187.89	188.50	188.19 b
Flat bed	168.86	168.44	168.65 c
Raised bed	196.83	200.19	198.51 a
LSD $_{(0.05)}$			1.36
Nitrogen (kg ha^{-1})			
60	153.75	155.06	154.40 c
120	187.61	189.19	188.40 b
180	212.22	212.89	212.56 a
LSD $_{(0.05)}$			1.07
Sulphur (kg ha^{-1})			
20	177.64	178.83	178.25 c
30	184.33	185.39	184.86 b
40	191.61	192.89	192.25 a
LSD$_{(0.05)}$			1.07
Year	184.53 b	185.71 a	*
Planned mean comparison			
Control	110.33	112.00	111.17
Rest	184.53	185.71	185.12
Interactions			
Y × SM	*	SM × S	
N × S		SM × N × S	
Y × N	ns	Y × SM × N	ns
Y × S	ns	Y × SM × S	ns
Y × N × S	ns	Y×SM×N×S	ns
SM × N			

*Mean followed different letters are statistically different from each at 5 % of probability; *: indicate significance at 5 % level of probability; ns: indicates not significant.*

kg ha^{-1}. Nitrogen and sulphur supplied plots resulted in an increase in plant height, while dwarf plants were produced in control plots. Significantly, taller plants (186 cm) were produced in year 2014, as compared with 2013. Taller Plants were produced with increase in both nitrogen and sulphur levels. Similarly, SM × N ×S interactive response was given in Figure 11 and was found significant for plant height. Plant height in case of flat sowing was lower than the other two sowing methods at each level of nitrogen and sulphur. Interaction between SMxN (Figure 9), and SMxS (Figure 10) follow same above trend for plant height, the contribution of sulphur negligible as compared with sowing method in Figure 11. The interactive response of nitrogen (N) and sulfur (S) was found significant for plant height (Figure 8). These variations in plant height might be due to good root establishment and development in raised bed with optimum utilization of available nutrients and water. Furthermore, high nitrogen and sulfur doses produce maximum amino acids, assimilates, chloroplast lipids, co-factors, co-enzymes, and photosynthates, which promotes plant height. Haruna (2011) mentioned that plant height increased with synergistic effects of sulfur and nitrogen nutrients in fertile soil.

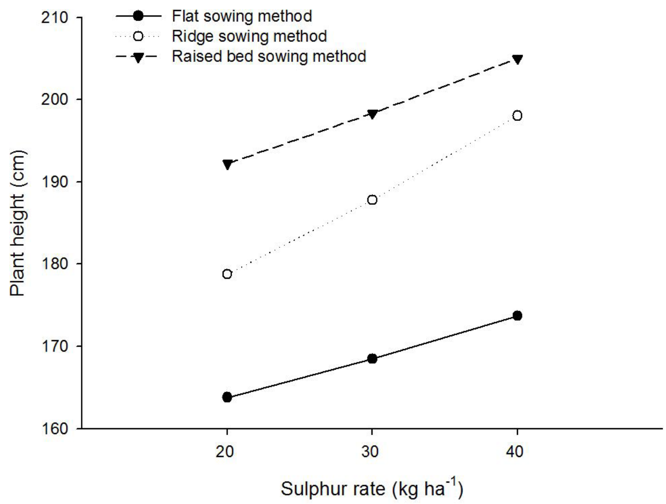

Figure 10: *Interaction between sulphur and sowing methods for plant height of sesame.*

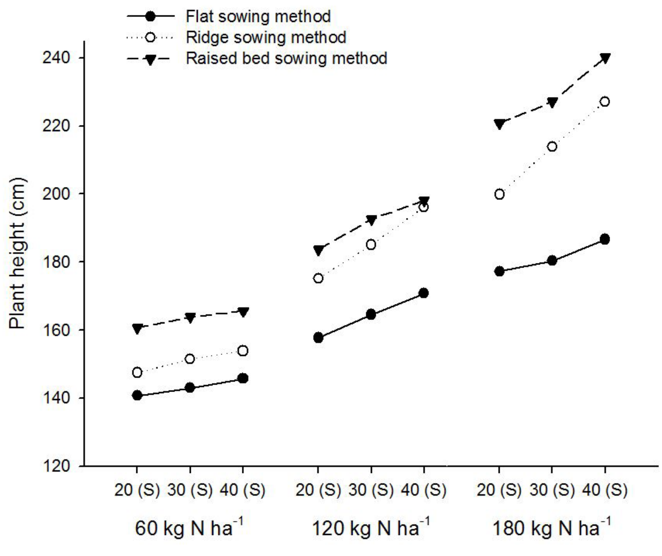

Figure 11: *Interaction between sowing methods, nitrogen and sulfur for plant height of sesame.*

Seed yield (kg ha^{-1})

Data exhibited in Table 7, are presenting seed yield and showed that combined two year of seed yield was significantly affected by different sowing methods, different nitrogen and sulfur fertilizer levels, whereas seed yield had significantly changed by year as a variant. Higher seed yield 1339 kg ha^{-1} was produced in raised bed. Application of nitrogen and sulfur fertilizer at 180 kg N ha^{-1} 40 Kg S ha^{-1} produced 1581 and 1346 kg ha^{-1} respectively. Maximum seed yield was gained in 2nd year of the experiment as compared with 1st year trail. Tabulated mean data showed that higher seed yield was obtained from fertilized (N and S) plots, as compared with no treated plots. The interactive response of NxS (Figure 12), and SMxNxS (Figure 13) was found significant for seed yield. Seed yield changes in sesame might be due to the optimum utilization of available nutrients for yield related parameters linked with good soil conditions. It also could be the combine synergistic effect of nitrogen and sulfur on plant growth and development, which

Table 7: *Seed yield (kg ha^{-1}) of sesame crop, as affected by sowing methods, nitrogen and sulfur levels during year 2013 and 2014.*

Sowing methods	2013	2014	Mean
Ridge	1285	1302	1294 b
Flat	1200	1255	1228 c
Raised bed	1330	1349	1339 a
LSD $_{(0.05)}$			34
Nitrogen (kg ha^{-1})			
60	988	986	987 c
120	1288	1298	1293 b
180	1540	1621	1581 a
LSD $_{(0.05)}$			21
Sulphur (kg ha^{-1})			
20	1208	1256	1232 c
30	1264	1302	1283 b
40	1344	1348	1346 a
LSD $_{(0.05)}$			21
Year	1272	1302	*
Planned mean comparison			
Control	601	661	631
Rest	1272	1302	1287
Significance			*
Interactions			
Y × SM	ns	SM × S	ns
N × S	*	SM×N×S	
Y × N	*	Y×SM×N	ns
Y × S	ns	Y × SM × S	ns
Y × N × S	ns	Y×SM×N×S	ns
SM × N	ns		

*Mean followed different letters are statistically different from each at 5 % of probability; *, **: indicate significance at 5 % level of probability; ns: indicates not significant.*

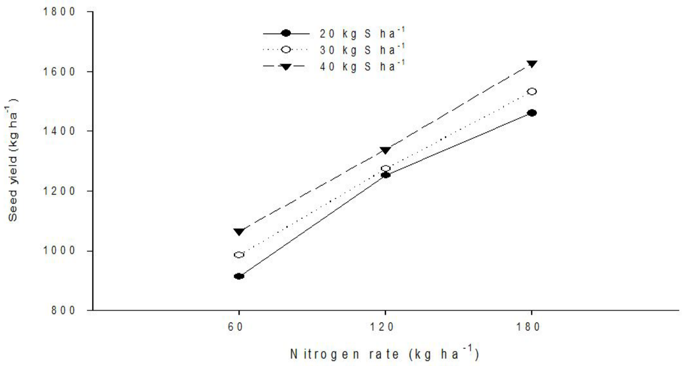

Figure 12: *Interaction between nitrogen and sulfur fertilizers for seed yield of sesame.*

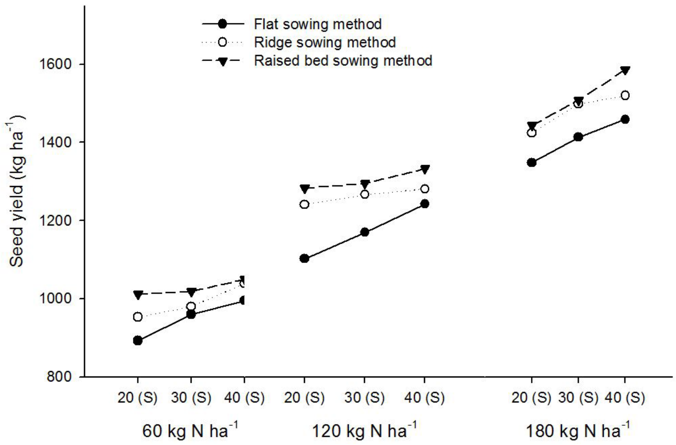

Figure 13: *Interaction sowing methods, between nitrogen and sulfur fertilizers for sesame seed yield.*

enhance branches, seed, capsule plant^{-1}, plant height and resulted in maximum seed production. Good soil condition with optimum N and S nutrients availability encouraged overall growth and development process of crops.

Conclusions and Recommendations

Sesame has tremendously responded to raised bed sowing method. Sowing of sesame on raised bed followed by ridge had significantly improved leaf, stem and yield parameters. Combined application of nitrogen at 180 kg ha^{-1} and sulphur 40 kg ha^{-1} had promoted yield related parameters and yield. The combined application of N and S at 180 kg ha^{-1} and 40 kg ha^{-1} in raised seed bed is recommended for achieving higher sesame yield production.

Novelty Statement

Novelty of this research is an adaptation of standard agronomic land management and nutrients management techniques, which can improve the productivity of sesame crops. Further, it has been revealed that sesame sown on well aerated loose soil of raised bed and ridge bed with combination of different nitrogen and sulphur fertilizers had improved yield and yield related parameters of the sesame.

Author's Contribution

Alam Zeb: Principal author, who conducted research, field experiments and analysis. Further, wrote draft of the manuscript.
Amanullah Jan: Major Supervisor, who supervised whole research study and provided technical guidelines.

Conflict of interest
The authors have declared no conflict of interest.

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