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Growth and yield parameters of okra (*Abelmoschus esculentus*) influenced by Diazotrophs and chemical fertilizers

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ABSTRACT

Field experiments were conducted during the summer seasons of 2010 and 2011 in College of Agriculture, Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, to assess the effect of diazotrophs (Biofertilizers - Azotobactor, Azospirillum, Phosphate Solubilizing Bacteria) and chemical fertilizers along with vermicompost on okra cv Mahyco-10 in terms of growth and yield. The experiment consisted of nine treatments including the control and replicated thrice in randomized block design. The maximum plant height (148.97 cm), leaf area (434.99 cm^2), number of nodes (30.16), fruit length (16.45 cm), fruit girth (1.62 cm), single fruit weight (18.70 g) and plant biomass-fresh weight (548.74 q ha^{-1}), were observed in the treatment receiving FYM@10 t ha^{-1} + 100% NPK + vermicompost @5 t ha^{-1} along with biofertilizers. The maximum number of fruits per plant was recorded with T_9 (FYM@10 t ha^{-1} + 75% NPK + vermicompost@5 t ha^{-1} + biofertilizers). Application of higher dose of fertilizers increased the fruit yield of okra considerably, where the yield varied between 80.24 q ha^{-1} to 228.38 q ha^{-1}. The study led to a conclusion, that the maximum growth parameters, highest yield and yield attributing characters of okra could be achieved by integrated use of diazotrophs, vermicompost and chemical fertilizers.

Key words: Diazotrophs, FYM, okra, vermicompost and yield

Okra is an important vegetable crop which supplies higher nutrition (carbohydrates, fats, protein, minerals and vitamins) in our diet. The main challenge before India is to increase the production of quality food in a sustainable manner and feeding the country's large population and increasing the income of the farmer. The requirements of fertilizers in okra are important for the early growth and total production of fruit yield. Integrated use of organic and inorganic fertilizers can improve crop productivity (Satyanarayana *et al*., 2002). The soil enriched with vermicompost provides additional substances that are not found in chemical fertilizers (Kale, 1998). Naidu *et al*. (2000) concluded that significant increase of microbes in soil was found with application of manures, vermicompost and biofertilizers. Inoculation with diazotrophs (*Azospirillum* , *Azotobacter* and PSB) in okra helped fixing atmospheric N, increased phosphate availability produced growth promoting and antifungal substances and finally increased the total yield. The objective of the study was to assess the effect of FYM, chemical fertilizers, vermicompost along with biofertilizers on okra in terms of growth and yield.

MATERIALS AND METHODS

Field experiment was conducted to evaluate the performances of okra variety *i.e.*, F1 hybrid (Mahyco-10) under different nutrient management practices. The mechanical composition were recorded as sand (84%), silt clay (16%) and clay (11%) and chemical composition as soil pH (5.34), available soil nitrogen (180 kg ha-1), available soil phosphorus (20 kg ha-1) and available soil potassium (120 kg ha-1).

The total precipitations during the cropping period recorded from February to June 2010 and 2011 were 190.9 mm and 249.1 mm respectively. The maximum and minimum temperatures during the first and second cropping year (2010) varied from 33.4°C to 39.2°C and 18.4°C to 24.3°C respectively.

The experiment was laid out in randomized block design with 3 replications. Altogether 27 plots of 9 m^2 each were prepared for the experiment. FYM@10 t ha^{-1} was applied in all the treatments as basal dose. The recommended N, P_2O_5 and K_2O fertilizer doses for F_1 Hybrid okra *i.e*. MAHYCO-10 was 200,100,100 kg ha^{-1}. Fertilizers were applied in split doses following during the cropping period. Vermicompost (5 t ha^{-1} and 2.5 t ha^{-1}) was also applied to the plot as per the requirement of the treatment. Further mixed culture of bio-fertilizers i.e. *Azotobactor, Azospirillum* and PSB (1:1:1) was used before sowing as per the treatments. The experiment consisted of nine treatments including the control treatment *viz.*, T_1 - Control (FYM @10 t ha^{-1}), T_2- FYM (10 t ha^{-1}) + 100 % RDF (NPK), T_3 - FYM (10 t ha^{-1}) + 75 % RDF(NPK), T_4 - FYM (10 t ha^{-1}) + 100 % RDF (NPK) + Bio-fertilizers [*Azotobactor, Azospirillum* and PSB (1:1:1) @6 kg ha^{-1}], T_5 - FYM (10 t ha^{-1}) + 75 % RDF (NPK) + Bio-fertilizers [*Azotobactor*, *Azospirillum* and PSB (1:1:1) @6 kg ha^{-1}], T_6 - FYM (10 t ha^{-1}) +100 % RDF (NPK)+ Vermicompost (5 t ha^{-1}) + Bio-fertilizers [*Azotobactor, Azospirillum* and PSB (1:1:1) @6 kg ha^{-1}], T_7 - FYM (10 t ha^{-1})+75 % RDF (NPK) +Vermicompost(2.5 t ha^{-1}) + Bio-fertilizers [*Azotobactor*, *Azospirillum* and PSB (1:1:1) @6 kg

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ha^{-1}], T_8 - FYM (10 t ha^{-1}) + 100% RDF (NPK) + Vermicompost (2.5 t ha^{-1}) + Bio-fertilizers [*Azotobactor, Azospirillum* and PSB (1:1:1) @6 kg ha^{-1}) and T_9 - FYM(10 t ha^{-1})+75 % RD (NPK) +Vermicompost (5 t ha^{-1}] + Bio-fertilizers [*Azotobactor, Azospirillum* and PSB (1:1:1) @6 kg ha^{-1}].

Ten plants were selected from each plot to record the biometric observations at various stages of crop growth. Growth parameters include plant height (cm), leaf area per leaf (cm^2), days to emergence of first flower and number of nodes per plant etc was measured prior to harvest. Post harvest observations *viz.*, fruit length, fruit girth, number of fruits, single fruit weight, plant biomass (fresh weight) and yield of the crop were recorded after harvesting. The mean data and physico-chemical estimates were subjected to proper statistical analysis as per Randomized Block Design system. The F-test was used for testing the significance of findings. Standard error for each factor was worked out to compare the means of two treatments. The Least Significant difference (LSD) was calculated at 5% level of significance.

RESULTS AND DISCUSSION

Plant height

The maximum plant height (148.97 cm) was obtained in T_6 when the highest amount of fertilizer (FYM@10 t ha^{-1} +100% RDF + vermicompost @5 t ha^{-1} + biofertilizer) dose was applied followed by FYM@10 t ha^{-1} + 100% RDF + vermicompost @2.5 t ha^{-1} + biofertilizer and both were statistically significant over rest of the treatments. The lowest plant height (110.90 cm) was recorded when the crop was grown with FYM only and sole application of inorganic fertilizers (100 % RDF or 75 % RDF) with FYM which resulted in poor performance as compared to the integrated application of fertilizers. It might be due to the increase in the nutrient availability and preponderance of different groups of microorganisms in soil, which create a favourable condition for proper vegetative growth in general and increased plant height in particular. The highest dose of nitrogen might have enhanced cell division and formation of more tissues resulting in luxuriant vegetative growth and thereby increasing plant height (Meyer and Anderson, 2003).

Leaf area

Significant differences were exhibited among different treatments with respect to leaf area. The highest (434.99 cm^2) and lowest (303.81 cm^2) leaf area were found in T_6 and T_1 respectively. From the present investigation, it is seen that there was a significant effect of application of FYM, 100% NPK along with vermicompost and biofertilizers on increasing the leaf area as compared to the control. The large leaf area might have contributed to the higher leaf dry weight grown with higher dose of potassium.

Number of nodes

The highest number of nodes (30.16) per plant was recorded in T_6 and the lowest (16.89) was in T_1. In okra, each node is a very important character for producing fruit. Application of FYM@10 t ha^{-1} + 100% RDF + vermicompost @5 t ha^{-1} and biofertilizer significantly increased the number of nodes per plant. This might be due to the better availability and uptake of plant nutrients, more specifically N, P and K, resulting in better photosynthesis and protein synthesis. Kumar *et al.* (2009) observed that application of 25% recommended dose of N through vermicompost significantly improved nodes per plant.

Number of days for emergence of first flower

The minimum number of days (37.40 days) taken for emergence of the first flower was in T_6 and the maximum number of days (45.02 days) taken was in control. This could be due to nitrogen and other inputs like vermicompost and biofertilizers which encouraged the differentiation of bud resulting in earlier flowering. Maximum number of days was required to flower where no minimum dose of fertilizer was applied; probably due to the nutrient stress resulting in late flowering. Earliness in days to flowering in okra was observed with the integrated nutrient application (chemical fertilizers, organic manures and biofertilizers) by Prabhu *et al*. (2002).

Nnumber of fruits

The highest (18.36) and lowest (10.39) numbers of fruits per plant were recorded in T_9 and T_1 respectively. The numbers of fruits per plant, the most important factor of fruit yield in okra were also significantly influenced by the combined application of chemical fertilizers, vermicompost and biofertilizer as compared to control. This might be due to the better availability and uptake of nutrients by plants for a longer duration of crop growth. Similar findings of significantly higher number of fruits per plant by integrated application of fertilizers have also been reported by Prabhu *et al*. (2003) in okra.

Fruit length and girth

The maximum (16.45 cm and 1.62 cm) and the minimum (9.99 cm and 1.39 cm) fruit length and girth were observed with highest dose of fertilizer i.e.FYM@10 t ha^{-1} 100% RDF + vermicompost @5 t ha^{-1} + biofertilizer. This might be attributed to the increased availability of NPK and water at the critical stages of the crop growth resulting early

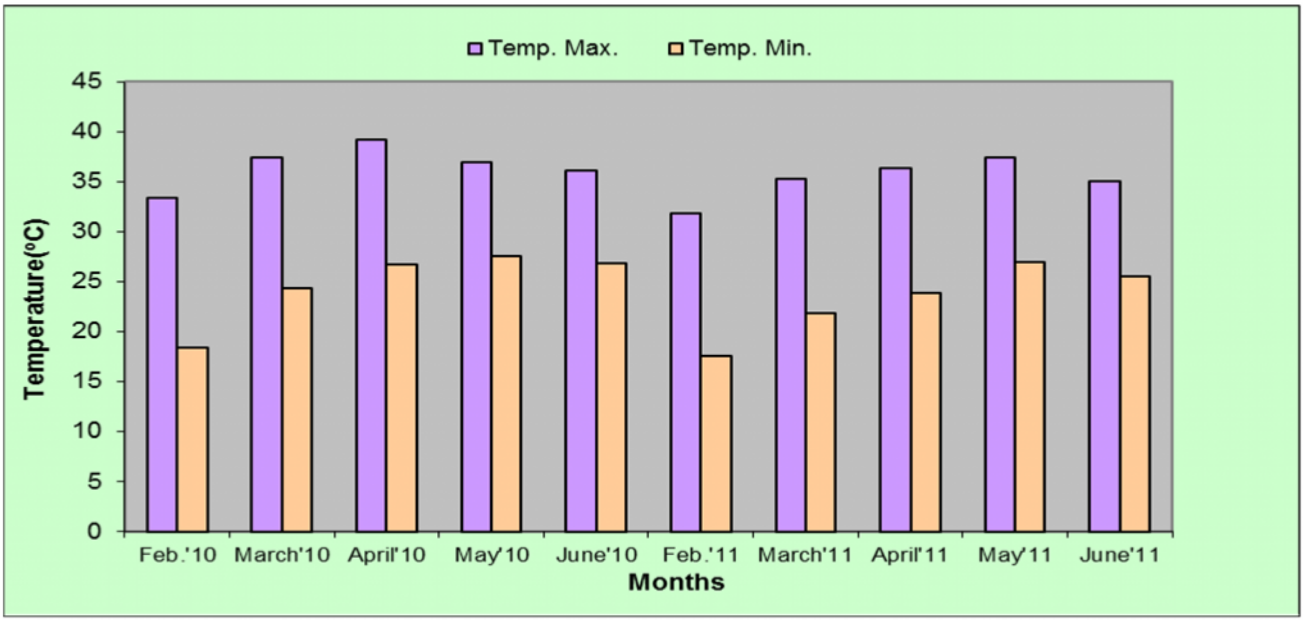

Fig. 1 Maximum and minimum temperatures during cropping season

Table 1: Effect of diazotrophs and chemical fertilizers on growth parameters of okra (Pooled)

	Treatments	Plant height (cm)	Leaf area (cm^2)	No. of nodes $plant^{-1}$	Days to emergence of 1^{st} flower	No. of fruits per $plant^{-1}$	Fruit length (cm)	Fruit girth (cm)	Single fruit weight (g)	Fruit yield (q ha^{-1})	Plant biomass-fresh weight (q ha^{-1})
T_1	Control (FYM 10 t ha^{-1})	110.90	303.81	16.89	45.02	9.99	1.39	11.62	80.24	387.38	10.39
T_2	T_1 + 100% RDF	135.22	369.48	26.05	39.93	14.69	1.57	15.33	172.96	448.03	16.94
T_3	T_1 +75% RDF	133.66	361.82	25.27	40.07	14.46	1.56	14.75	168.64	442.93	17.17
T_4	T_1 +100% RDF + Bio-fertilizer	138.88	389.89	26.93	39.59	15.05	1.58	16.07	183.58	469.28	17.14
T_5	T_1 +75% RDF + Bio-fertilizer	137.68	380.38	26.14	39.65	14.94	1.58	16.03	179.70	461.29	16.85
T_6	T_1 + 100% RDF + Vermicompost(5 t ha^{-1}) + Biofertilizer	148.97	434.99	30.16	37.40	16.45	1.62	18.70	228.38	548.74	18.33
T_7	T_1 + 75% RDF +Vermicompost(2.5t ha^{-1}) +Biofertilizer	141.18	400.58	27.75	39.27	15.37	1.60	17.19	203.67	496.23	17.79
T_8	T_1 +100% RDF +Vermicompost(2.5t ha^{-1}) +Biofertilizer	144.95	416.96	29.11	38.86	15.98	1.61	17.88	211.25	507.32	17.75
T_9	T_1 +75% RDF +Vermicompost(5 t ha^{-1}) + Biofertilizer	142.27	408.22	28.42	38.32	16.23	1.60	17.47	213.71	517.12	18.36
	SEm(±)	**0.19**	**0.85**	**0.16**	**0.16**	**0.16**	**0.01**	**0.12**	**0.713**	**0.29**	**0.14**
	LSD(0.05)	**0.56**	**2.44**	**0.45**	**0.45**	**0.46**	**0.02**	**0.34**	**2.04**	**0.83**	**0.39**

Note: RDF - Recommended dose of fertilizer

establishment, vigorous growth and development of plants leading to longer and wider fruits. Higher value in fruit girth of okra observed due to integrated application of application of fertilizers by Naidu *et al.* (2002).

Fruit weight

The maximum (18.70 g) and the minimum (11.62 g) weight of the single fruit increases with treatment T_6 and T_1 respectively. This might occur due to increased photosynthetic area and translocation of photosynthates in plants which subsequently accelerated the formation of more number of large sized fruits with more number of seeds per fruits resulting in increase in fruit weight.

Fruit yield

The maximum yield (228.38 q ha^{-1}) was recorded in T_6 which was significantly superior to rest of the treatments tried in the experiment. However, as expected the lowest yield (80.24 q ha^{-1}) was recorded in T_1. Jayapandi and Balakrishnan (1990) made a correlation study of yield components in okra and reported that characters like days to flowering, plant height, nodes per plant, fruit length, fruit weight and fruits per plants were significantly and positively correlated with the yield. Use of biofertilizers can replace the application of 75% of the recommended dose of nitrogen and phosphorus chemical fertilizers (El-Shaikh, 2005). It is evident from the experiment that the enhancement in plant growth attributes by the application of FYM@10 t ha^{-1}, nitrogenous fertilizer as 100% of the needed requirements plus vermicompost @5 t ha^{-1} and the inoculation with bio-fertilizers reflected on the total pod yield. Similar results were reported earlier by Jha and Mathur (1993).

Plant biomass

The maximum plant biomass (548.74q ha^{-1}) were recorded in V_1T_6 (FYM@10 t ha^{-1} + 100% RDF + vermicompost @5 t ha^{-1} + biofertilizer) followed by V_1T_9 (517.12q ha^{-1}), V_1T_8 (507.32q ha^{-1}) and V_1T_7 (496.23 q ha^{-1}). This is might be due to integrated application of nutrients with higher dose of nitrogenous fertilizers which increased the dry matter content. Shanthi and Vijaykumari (2002) recorded higher fresh plant weight due to the integrated use of NPK and neem cake at 30 days after sowing in okra cv Arka Anamika.

The present investigation reveals that the maximum vegetative growth, yield attributing characters and fruit yield was found in integrated application of fertilizers as compared to recommended dosage of chemical fertilizers and organic manure alone. It is due to the effective utilization of N, P, K by the application of FYM@10 t ha^{-1} + 100% of the recommended dose of NPK along with diazotrophs in presence of vermicompost @5 t ha^{-1}.

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Effect of sulphur on seed yield and oil content in safflower

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ABSTRACT

The experiment was carried in District Seed Farm 'D' Block, Kalyani, Nadia with four varieties of safflower and four different treatments in four replication in split-plot design. The four treatments were: application of sulphur @ 20,40 and 60kg sulphu. ha^{-1} along with control i.e., without application of sulphur. Among the treatments application of sulphur @ 20 $kg.ha^{-1}$ and 40 $kg.ha^{-1}$ was found most effective for increment of seed yield and oil yield respectively for safflower.

Key words: Biological yield, oil content and sulphur application

Among the minor oil seed crops in India safflower (*Carthamus tinctorious*) is one of the most important crop owing to its various use and special qualities. The crop is being cultivated for centuries in India either for its orange-red dye extracted from its brilliantly coloured florets and/or for its much-valued oil; but the crop is now grown mainly for edible oil extracted from seed. Seeds of safflower contain 24-36% oil (Singh, 1983). Sulphur is now recognized as the fourth major nutrient next to nitrogen, phosphorus and potash. It plays a vital role in formation of chlorophyll, activation of enzymes and improvement in both crop yield and oil yield (Tandon, 1995). Keeping in view the importance of sulphur(S), the field experiment was conducted for consecutive two years on varying response of four safflower varieties towards sulphur application for both seed and oil yield.

MATERIALS AND METHODS

The present study was conducted during *rabi* season of 2006-07 and 2007-08 in District Seed Farm 'D' Block,Kalyani and in the Department of Seed Science and Technology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal. Provide lat-long and other conditions of the experimental site. The experiment was carried out with four different varieties of safflower viz., A1, A200, A300 and Bhima. Before flowering, three different doses of sulphur: viz, 20 (T_1), 40 kg.ha-1 (T_2) and 60 kg.ha-1 (T_3) follow journal style in form of gypsum was applied on the root zone of the crop and incorporated into the soil to assess the effect of sulphur. The experiment was carried out in split plot design with four replications placing the varieties in the main plot and treatments in the sub-plot. Number of treatments within each sub-plot were four (including control T_0, without S-application) and there were five rows of five(5) meters length for each treatment leaving one row gap/blank between two consecutive treatments. After harvesting seed yield $g.plant^{-1}$ was recorded and oil content of produced seeds were estimated following the method described by Sadasivam and Manickam (1992).

RESULTS AND DISCUSSION

Average seed yield per plant was consistently high for A200 irrespective of the years and pooled condition followed by A300, A1 and Bhima. performance of A_{300}, A1 and Bhima were noted to be statistically at par with each other in the first year and pooled condition while it were A1 and Bhima in second year. Comparatively better performance of all the varieties in first year may be due to the better potential expression of component characters subjecting to favourable climatic conditions. Maximum seeds yield per plant was recorded after application of S @ 20 $kg.ha^{-1}$, when average was made over varieties, though it was statistically at par with application of S @ 60 $kg.ha^{-1}$ over the years. It is to be noted that S-application @ 40 kg $.ha^{-1}$ could not be able to influence in enhancing seeds yield over control. Therefore, economic consideration of seed production may suggest to recommend pre-flowering application of S @ 20 $kg.ha^{-1}$ provided other factors remain unaffected. While considering the interaction effects, highest magnitude in seed yield per plant could be observed after A200 when sulphur was applied with 40 $kg.ha^{-1}$ (T_2) in first year and pooled condition, while it was A300 in second year when applied with 60 kg $S.ha^{-1}$ (T_3). Response of individual varieties towards application of sulphur with varying doses can be noted in different manner: A_{200} is the only variety for which no significant response could be recorded over the years, significantly best response towards 20 kg $sulphur.ha^{-1}$ was recorded for $A_{1,}$ significantly similar positive response towards both 20 kg and 60 kg $sulphur.ha^{-1}$ was noted for A_{300}, while Bhima responded best after 60 kg $sulphur.ha^{-1}$,which indicated the existence of variety-specific response in enhancing for production of seeds per plant. Significant influence of sulphur on yield and yield attributes in Safflower has also been observed by Dashora and Sharma (2006), which corroborates the present findings.

Significant varietal differences could be noticed for its average oil content in both the years

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and pooled condition. Significant treatment influence i.e., pre-flowering S-application with different dose in soil as well as interaction effect were also noticed in all situations.

Average oil content (%) was consistently highest after Bhima followed by A300, A200 and A1 over the years of experiment as well as in pooled condition. All the varieties were found to be significantly different from each other with almost similar performance over the years especially for this character, which may be due to the typical expression of its genetic control. Application of sulphur both @ 40 and 60 kg.ha^{-1} influenced the enhancement in average oil content of seed in significantly similar manner irrespective of the years and it is to be noted also that average oil content was also enhanced even after application of 20 kg S.ha^{-1} over control (without S-application).While considering the interaction effects, significantly highest oil content was observed after Bhima when it was applied with both 40 and 60 kg.ha^{-1} S in both the years and in pooled condition. Whereas, the lowest oil content was recorded after A1 in control *i.e.*, without S-application. The varieties responded towards S-application with varying doses in very variety specific manner irrespective of the year. Oil content of A1 and Bhima enhanced with the increase in S-doses, it was reduced over control in A200 after application of 20 kg.ha^{-1} S and then enhanced, and no significant differences could be sorted out for oil content of A300 due to doses of S-application, though superior to that of control. Considering the capability of higher S-doses in influencing this parameter, application @ 40 kg.ha^{-1} may be effectively utilized for enhancement in oil content of safflower. Observation of Prakash and Singh (2002) on enhancement in oil content in Indian mustard after sulphur application upto 40 kg.ha^{-1} corroborate the findings of the present investigation. Contradiction with the observation of Dashora and Sharma (2006) on enhancement in oil content upto 60 kg.ha^{-1} S may be due to utilization of single variety in their experiment with different genetic make-up. Though varietal response towards sulphur application in enhancement of seed yield and oil content was observed to be in genotype specific manner, application of 40 kg.ha^{-1} S, on an average, may be recommended for safflower while enhancement in both seeds and oil yield in concern.

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Table1:Variation in seed yield plant^{-1} (gm) among safflower varieties as influenced by sulphur application

	1st Year					**2nd Year**					**Pooled**				
	T_0	**T_1**	**T_2**	**T_3**	**MEAN**	**T_0**	**T_1**	**T_2**	**T_3**	**MEAN**	**T_0**	**T_1**	**T_2**	**T_3**	**MEAN**
V_1	8.45	10.45	8.05	6.55	8.37	7.40	9.70	7.40	6.15	7.66	7.92	10.07	7.72	6.35	8.02
V_2	10.75	10.80	11.25	10.25	10.76	10.20	10.20	10.65	9.65	10.17	10.47	10.50	10.95	9.95	10.47
V_3	7.75	10.45	7.20	10.45	8.96	7.35	9.80	6.90	10.90	8.73	7.55	10.12	7.05	10.67	8.87
V_4	8.55	7.05	8.35	9.50	8.36	7.05	7.55	7.10	8.90	7.65	7.80	7.30	7.72	9.20	8.01
Mean	8.87	9.68	8.71	9.18		8.00	9.31	8.01	8.90		8.43	9.50	8.36	9.04	

	SED	**LSD (0.05)**	**LSD**	**SED**	**LSD (0.05)**	**LSD**	**SED**	**LSD (0.05)**	**LSD**
V	**0.347**	**0.787**	**1.130**	**0.291**	**0.659**	**0.946**	**0.278**	**0.630**	**0.905**
T	**0.355**	**0.721**	**0.967**	**0.264**	**0.535**	**0.718**	**0.283**	**0.574**	**0.770**
V x T	**0.707**	**1.474**	**2.014**	**0.542**	**1.136**	**1.550**	**0.564**	**1.176**	**1.607**

Table 2: Variation in oil content (%) among safflower varieties as influenced by sulphur application

	1st Year					**2nd Year**					**Pooled**				
	T_0	**T_1**	**T_2**	**T_3**	**MEAN**	**T_0**	**T_1**	**T_2**	**T_3**	**MEAN**	**T_0**	**T_1**	**T_2**	**T_3**	**MEAN**
A_1	26.55	26.90	29.76	29.45	28.16	25.82	26.59	29.80	29.54	27.94	26.19	26.74	29.78	29.50	28.05
A_{200}	28.36	27.51	28.98	29.04	28.46	28.13	27.35	28.65	28.90	28.26	28.25	27.43	28.82	28.97	28.37
A_{300}	29.56	30.85	30.77	31.03	30.55	29.43	30.61	30.62	30.79	30.37	29.45	30.73	30.70	30.91	30.46
Bhima	30.25	31.02	31.50	31.35	31.03	30.10	30.87	30.97	31.28	30.80	30.18	30.94	31.23	31.32	30.92
Mean	26.68	29.07	30.25	30.22		28.37	28.85	30.01	30.13		28.53	28.96	30.13	30.17	

	SED	**LSD (0.05)**	**LSD**	**SED**	**LSD (0.05)**	**LSD**	**SED**	**LSD (0.05)**	**LSD**
V	**0.063**	**0.134**	**0.185**	**0.109**	**0.232**	**0.320**	**0.729**	**0.154**	**0.213**
T	**0.063**	**0.134**	**0.185**	**0.109**	**0.232**	**0.320**	**0.729**	**0.154**	**0.213**
V x T	**0.127**	**0.269**	**0.371**	**0.219**	**0.465**	**0.641**	**0.145**	**0.309**	**0.426**