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Effect of Planting Methods in Different Sesame (*Sesamum indicum* L.) Varieties during the Summer Season

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ABSTRACT

A field experiment was conducted during the summer seasons (2nd week of March to 3rd week of June) of 2019 and 2020 at the District Seed Farm, 'AB' block, Kalyani at Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India to evaluate the effect of line sowing and broadcasting methods of different varieties of sesame for good growth and yield. The experiment was laid down in 2×8 factorial RBD with replicated three times having two methods of sowing viz. S_1: Line sowing; S_2: Broadcasting was in the main block and eight varieties viz. V_1: GT_1; V_2: GT_2; V_3: GT_3; V_4: GT_4; V_5: GT_5; V_6: GT_6; V_7: GT_{10}; V_8: Savitri was in the sub-block. Results revealed that plant height, rooting depth and root mass were considerably influenced by sowing methods and higher value was found under line sowing. Plant establishment methods did not vary a number of primary branches plant^{-1}, LAI, CGR and dry matter production significantly but varied among varieties. Maximum number of capsule plant^{-1} was found under line sowing and the highest value was recorded in the variety GT_4. Line sowing responded more yield a tune of 8.26% as compared to broadcasting. Oil content in the 43–47% range was registered under different varieties and the highest (47.7%) was recorded in the variety V_5. Under line sowing protein content was found maximum with the variety V_4. A higher benefit-cost ratio (1.82) was noted under the broadcasting method compared to line sowing (1.76).

KEYWORDS: Sesame, line sowing, broadcasting, varieties, yield, economics

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1. INTRODUCTION

Sesame, (*Sesamum indicum* Linn.), one of the most important edible oilseeds is perhaps the oilseed known and used by human beings (Joshi, 1961; Weiss, 1983). It has been cultivated in Asia for over 5000 years (Troncoso et al., 2011). Sesame is an ancient oilseed crop and it is widely cultivated in Asia and Africa (Kurdistani and Tohidinejad, 2011). It is an important source of high-quality oil and protein (Jhonson et al., 1979, Elleuch et al., 2007) and the oil content ranges from 34 to 63% (Were et al., 2006). The oil has excellent stability due to the presence of natural antioxidants such as sesamolin and sesamin (Bedigian et al., 1985) known to have a cholesterol-lowering effect in human and to prevent high blood pressure (Anilakumar et al., 2010). The presence of sesamol, an anti-oxidant and more polyunsaturated fatty acid, has made it to 'queen of oilseed crop' (Ashri, 1998 and Fukuda et al., 1986). In India, sesame occupies an area of 1.73 m ha with a production of 0.82 mt and productivity of 474 kg ha^{-1} (Anonymous, 2021). The productivity of sesame is low in India (431 kg ha^{-1}) compared to the world average (512 kg ha^{-1}) (Anonymous, 2018). Low productivity in sesame is attributed to a lack of high-yielding varieties and traditional production technologies. The major constraints in sesame cultivation are a lack of high-yielding varieties, poor stand establishment and poor fertilizer response (Alex et al., 2017). Because, almost in most of the sesame growing areas in India as well as in West Bengal, sowing through broadcasting is the most common practice because of the ease of broadcasting and lack of proper sowing equipment. Imoloame et al., 2007, claimed that one of the main factors contributing to the nation's low sesame yield is the improper use of sowing techniques. It was further confirmed by Islam et al., 2008, that the line-sowing method for sesame was superior to the broadcast method. Although sesame being a stress-tolerant hardy crop, modern high-yielding varieties have a wider genetical plasticity with higher yield potentiality has tremendous scope to raise good options to increase the area by enhancing productivity to follow the suitable agro-techniques in irrigated ecosystems. Sesame had more preference from farmers because of the low input requirement and the high price of produce (De et al., 2013). Despite all these, it has not contributed enormously to the total oil seed production in India, mainly because of low productivity (417.2 kg ha^{-1}) (Anonymous, 2018). For breaking the present yield barrier and evolving varieties with high yield potential, it is desirable to combine the genes from genetically diverse parents (Wadikar et al., 2019). Hence, there is a need to enhance the productivity of this crop by developing high-yielding varieties, which depends on the availability of variability for seed yield and its component traits in the populations (Gopal et al., 2020). The phenotypic and genotypic variations of the yield contributing characters are considerably high in sesame (Sivaprasad et al., 2013 and Teklu et al., 2014), which points out the possibility of developing and identifying a variety with high yield. According to Kumaresan and Nadarajan, 2002, different sesame varieties yielded differently in different environments. In keeping this view, it was considered worthwhile to take an investigation for enhancing the sesame yield by resorting to and adopting of proper sowing method and selection of most suitable high-yielding varieties suited to this agro-climatic condition.

2. MATERIALS AND METHODS

The experiment was carried out at the District Seed Farm, Kalyani, under Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India (23.5°N, 89.0°E) during the summer seasons (2^{nd} week of March to 3^{rd} week of June) of 2019 and 2020. The soil in the test field had an alluvial texture and was sandy loam. It had a good water-holding capacity (WHC), medium fertility status, and neutral reactivity (pH 7.1). The temperature during the period of experimentation (February 2019 to May 2019 and February 2020 to May 2020) ranges between 14.6°C to 36.1°C in 2019–20 and between 12.7°C to 33.9°C in 2020–21, respectively. The experiment was carried out in 2x8 factorial RBD with three replications where two methods of sowing viz. S_1: Line sowing; S_2: Broadcasting was in the main block and eight varieties viz. V_1: GT_1; V_2: GT_2; V_3: GT_3; V_4: GT_4; V_5: GT_5; V_6: GT_6; V_7: GT_{10}; V_8: Savitri in sub-block. The sub-block size was 4x 3 m^2 and the field was prepared as per required to obtain a desirable tilth. Before sowing, Seeds were treated with Trichoderma 5 g kg^{-1} of seed and then seeds were sown in broadcast and line sowing method maintaining 30 cm row to row with continuous seeding (10 cm plant to plant distance after thinning). The sources of nitrogenous, phosphatic and potassic fertilizers were urea, single superphosphate (SSP) and muriate of potash (MOP) respectively and the entire amount of 80 kg N, 40 kg P_2O_5 and 40 kg K_2O were given as basal. Two irrigations were followed as per the treatment schedule during the pre-flowering and early pod developmental stages. The intercultural operations like thinning, weeding and plant protection measures were done as necessary.

Five randomly chosen representative plants from each plot of each replication were observed for various growth parameters, and according to the standard procedure, yield and yield-attributing characters were also recorded. The physiological maturity stage also included the recording of yield attributes. The net plot area of each treatment was used to record the seed and straw yield. The crop was harvested when 80% of pods were matured then threshed, cleaned and sun-dried to record grain yield. The Soxhlet method was used to determine the oil content of seeds, and the oil yield was calculated by multiplying the seed yield by the oil per cent of the corresponding treatments.

The recorded data were pooled and analysed using the analysis of variance with the help of the computer package SPSS. Fisher and Snedecor's F test for appropriate degrees of freedom was used to assess the importance of different sources of variation, and the computation of critical difference (CD) was done at a level of significance of 5%. Correlation and regression among the various growth, yield and physiological parameters were done with the help of the SPSS computer package.

3. RESULTS AND DISCUSSION

3.1. Growth parameters

Plant height did not vary significantly at the early stage but with the advancement of the crop age, significantly higher plant height was found under line sowing as compared to broadcasting. Plant height increased with increasing the age of the crop in all the varieties but maximum plant height was recorded under the variety V_7 (GT_{10}) which was significantly superior to the rest of the treatments during all the growth stages. The interaction effect among the method of sowing and variety did not show significant results. The sowing method had a significant influence on rooting depth and root mass and a higher value was recorded under line sowing. Different varieties have different rooting depths and root masses but higher rooting depth was recorded at V_7 (21.2 cm) at 30 DAS; V_4 (33.1 cm) at 60 DAS and in root mass it was V_7 and V_5 at 30 DAS and 60 DAS, respectively. A number of primary branches plant^{-1}, LAI and CGR did not vary significantly due to different plant establishment methods. No significant differences in primary branches were exhibited among varieties of sesame. Different LAI was recorded under different varieties and the highest LAI was recorded under the variety V_5 (GT_5). A higher growth rate was noticed at 31–60 DAS in all the varieties and maximum CGR was found under the variety V_2 (GT_2). Irrespective of the varieties, the growth rate decreased with the increase in the crop age towards maturity. The method of sowing had no significant influence on dry matter production. Maximum dry matter production was recorded under the variety V_2 (GT_2) which was significantly superior to the rest of the varieties. (Table 1).

Table 1: Effect of sowing methods and varieties on different growth parameters of sesame

Treatment	Plant height (cm)			Rooting depth (cm)		Root weight (g)		No. of primary branches plant^{-1}	Leaf area index		Crop growth rate (g m^{-2} day^{-1})		Dry matter accumulation (g m^{-2})	
	30 DAS	60 DAS	AH	30 DAS	60 DAS	30 DAS	60 DAS	AH	30 DAS	60 DAS	31-60 DAS	61-harvest	60 DAS	AH
Sowing method (S)														
S_1: (Line sowing)	68.9	92.8	131.2	18.9	31.8	14.4	21.4	2.5	1.5	3.7	6.65	1.70	324.4	375.0
S_2: (Broad-casting)	66.6	93.7	128.5	17.1	29.6	13.0	19.4	2.5	0.6	2.8	6.41	1.69	315.3	362.2
SEm±	0.50	0.44	0.66	0.13	0.28	0.08	0.11	0.11	0.01	0.09	0.13	0.18	1.14	1.61
LSD (p=0.05)	NS	1.27	1.90	0.37	0.81	0.23	0.32	NS	NS	0.26	NS	NS	3.28	4.63
Variety (V)														
V_1: GT_1	64.7	93.8	121.1	19.5	32.6	14.3	21.0	1.8	1.2	3.2	6.31	1.84	310.0	358.2
V_2: GT_2	63.7	88.6	120.6	16.3	29.5	13.2	19.3	1.9	1.1	3.4	7.01	2.02	336.6	389.8
V_3: GT_3	69.3	95.9	139.8	15.6	27.6	12.9	18.7	1.9	0.9	3.1	6.28	1.92	311.4	363.3
V_4: GT_4	66.3	95.5	130.0	20.3	33.1	15.0	20.4	3.2	0.8	2.9	6.69	2.01	326.5	382.6
V_5: GT_5	65.7	94.0	127.0	16.9	30.9	13.2	22.3	2.3	1.3	3.4	6.51	1.58	319.5	366.3
V_6: GT_6	68.8	93.6	134.4	17.2	29.8	13.7	19.4	1.5	1.1	3.1	6.54	1.41	318.6	359.0
V_7: GT_{10}	78.7	98.4	147.2	21.2	32.3	14.2	21.3	3.7	1.2	3.3	6.53	1.44	318.3	362.2
V_8: Savitri	64.6	86.4	118.9	17.0	29.7	12.8	20.7	3.7	0.9	3.4	6.49	1.38	317.8	367.3
SEm±	0.99	0.88	1.32	0.16	0.31	0.19	0.24	0.22	0.03	0.10	0.17	0.24	2.28	3.22
LSD (p=0.05)	2.85	2.53	3.80	0.45	0.89	0.54	0.69	NS	0.09	0.29	0.49	NS	6.53	9.23

AH: At harvest

3.2. *Yield attributes*

The phenological observations such as 50% flowering and days to maturity were not considerably affected by sowing methods and varieties. Sowing methods had a significant influence on the number of capsule plant^{-1} and a significantly higher value (48.2) was recorded with S_1 (line sowing) as compared to S_2 (Broadcasting). (Table 2). This might be due to desired plant populations providing better micro-climate which reduces the inter and intra-plant competition for nutrients, light, moisture etc. in line sowing whereas in broadcasting method, was very competitive as the plant population was more and planting geometry was irregular. Shekh et al. (2012) and Patel et al. (2014) claimed that line sowing gave a more and significant number of capsules as compared to broadcasting. Number of capsules of the plant varied significantly among different varieties and significantly higher capsules (60.7) were found in the variety V_4 which was statistically at par with V_8 but significantly superior to the rest of the varieties. Variety GT_{10} (V_7) gave a higher 1000 seed weight as compared to other varieties. (Table 2)

Table 2: Effect of sowing methods and varieties on yield attributes of sesame

Treatment	Associate characters of yield attributes			Yield attributes	
	Length of capsule (cm)	Days to 50% flowering (mean value)	Days to maturity (mean value)	No. of capsule plant^{-1}	1000 seed weight (g)
Sowing method (S)					
S_1: (Line sowing)	2.7	42	90	48.2	3.6
S_2: (Broadcasting)	2.7	43	89	45.9	3.7
SEm±	0.05	-	-	1.82	0.08
CD (p=0.05)	NS	-	-	5.24	0.23
Variety (V)					
V_1: GT_1	2.3	42	87	40.8	3.5
V_2: GT_2	2.8	40	87	53.4	3.4
V_3: GT_3	2.8	41	88	51.3	3.5
V_4: GT_4	3.1	41	88	60.7	3.7
V_5: GT_5	2.4	43	90	41.4	3.5
V_6: GT_6	2.2	42	89	37.2	3.6
V_7: GT_{10}	3.1	41	91	33.8	4.6
V_8: Savitri	0.10	47	96	58.1	2.8
SEm±	0.18	-	-	1.11	0.16
CD (p=0.05)	NS	-	-	3.19	0.46

3.3. *Yield*

The seed yield of sesamum was significantly affected by planting methods. Line sowing responded more yield a tune of 8.26% as compared to broadcasting and this could be achieved due to the uniform and desired plant population which provided sufficient space for light interception as well as less competition with other resources like moisture, nutrients, weeds etc. as compared to broadcasting where more competition was happened with water, nutrient, weeds, other environmental factors etc. as a result of irregular and unpredictable crop growth. Therefore, the phenotypic characters of the plant were highly variable and a significant reduction in the yield was recorded at broadcasting method. A similar finding was also reported by Shekh et al. (2012). Higher seed yield (1482 kg ha^{-1}) was obtained with the variety (GT_2) owing to a higher number of capsules plant^{-1} including other growth-promoting characters. The varieties V_2 and V_4 were statistically at par with each other but significantly superior to the rest of the varieties. This result also confirms the finding of Monpara et al. (2018). Higher stem yield (3750 kg ha^{-1}) was found under line sowing with the variety V_2 (GT_2). Harvest index did not vary significantly due to different methods of plant establishment but among the varieties, they differed significantly (Table 3).

3.4. *Oil and protein content*

The method of sowing had no significant influence on oil content. Oil content in the range of 43–47% was registered under different varieties, highest (47.7%) was recorded in

Table 3: Effect of sowing methods and varieties on yield and yield components of sesame

Treatment	Yield (kg ha^{-1})		Oil content		Protein content (%)	Harvest index (%)	BCR
	Seed yield	Stem yield	Oil (%)	Oil yield (kg ha^{-1})			
Sowing method (S)							
S_1: (Line sowing)	1310	3750	45.7	599	28.2	25.9	1.76
S_2: (Broadcasting)	1210	3621	45.6	552	26.8	25.0	1.82
SEm±	12.43	16.08	0.24	-	0.99	0.19	-
CD (p=0.05)	35.79	46.31	NS	-	2.85	NS	-
Variety (V)							
V_1: GT_1	1127	3582	45.1	508	28.3	23.9	1.60
V_2: GT_2	1462	3898	46.8	685	27.3	27.3	2.08
V_3: GT_3	1189	3632	46.7	555	26.8	24.7	1.70
V_4: GT_4	1456	3825	45.3	656	28.3	27.5	2.06
V_5: GT_5	1226	3662	47.7	585	27.2	25.1	1.75
V_6: GT_6	1191	3640	43.8	522	25.9	24.9	1.69
V_7: GT_{10}	1177	3622	45.5	535	26.1	24.5	1.67
V8: Savitri	1259	3673	44.6	562	28.2	25.6	1.79
SEm±	24.86	32.16	0.48	-	1.03	0.39	-
CD (p=0.05)	71.59	92.62	1.38	-	2.95	1.12	-

the variety V_5 (GT_5) and the lowest (43.6%) was in V_6 (GT_6). Under line sowing protein content was found maximum as compared to broadcasting. Higher protein content was recorded under the variety V_4 (GT_4) but it was statistically at par with other varieties (Table 3).

3.5. *Economics*

A higher benefit-cost ratio (1.82) was noted under the broadcasting method of seed sowing as compared to line sowing (1.76). This happened due to the lower cost of cultivation as compared to line sowing. However, they were much closed. (Table 3)

3.6. *Correlation study*

In a correlation analysis of sesame growth and yield attributes, seed and stem yield, and physiological parameters, it was discovered that the seed yield was positively correlated with dry matter production at 60 DAS and harvest, the number of primary branches, capsule length, days to maturity, capsule plant^{-1}, and stem yield. In contrast, it is negatively correlated with plant height at all stages, days to 50% flowering, and seed weight at 1000. Sesame seed yield is highly influenced by the dry matter production at 60 DAS, at harvest, and the yield of the stem. It is also critical to consider how the number of capsules plant^{-1} impacts seed yield (Table 4).

3.7. *Regression study*

In a regression analysis of various growth and yield attributes, seed yield, and physiological parameters of sesame, we observed that stem yield, plant height at 30 days of development, dry matter production at 60 days of development, number of primary branches, days to flowering at 50%, days to maturity, number of capsule plants^{-1} and 1000 seed weight were key parameters that influence sesame seed yield. (Table 5). Using the regression analysis described above, the following equation could be derived:

Seed yield=-3354.56+0.085×stem yield+24.65×Days to 50% flowering-13.96×days to maturity

3.8. *Association among the traits*

In any selection Programme, association analysis of characteristics is an essential method. It helps to define the component qualities on which selection may be based for the aim of genetic improvement in yield by giving an idea of the relationship between the various qualities. The efficacy of the selection process is also influenced by the degree of relationship. The correlation coefficient analysis is a measure of how closely two variables are related.

Based on the outcome of the calculation (Figure 1), highly significant positive correlations between the traits have been quantified and represented by large blue circles that are boxed and on the contrary, the negative correlations are represented via red circles. Such correlations were detected between P_{30}DAS and P_{HARV}, P_{60}DAS and P_{HARV}. Likewise, DM_{30}DAS has shown highly significant positive correlations with DM_{60}DAS, DM_{HARV}, and CGR-31,

Table 4: Correlation of sesame seed yield with the growth and yield attributes and the physiological parameters

	Seed yield	Plant height at 30 DAS	Plant height at 60 DAS	Plant height at harvest	Dry matter production at 60 DAS	Dry matter production at Harvest
Seed yield	1.000	-0.279	-0.284	-0.246	0.876**	0.969**
Plant height at 30 DAS	-0.279	1.000	0.557	0.891**	-0.088	-0.220
Plant height at 60 DAS	-0.284	0.557	1.000	0.725*	-0.319	-0.319
Plant height at harvest	-0.246	0.891**	0.725*	1.000	-0.135	-0.229
Dry matter production at 60 DAS	0.876**	-0.088	-0.319	-0.135	1.000	0.914**
Dry matter production at harvest	0.969**	-0.220	-0.319	-0.229	0.914**	1.000
Number of primary branches	0.128	0.333	-0.036	0.113	0.103	0.114
Length of capsule	0.266	0.408	0.393	0.516	0.131	0.274
Days to 50% flowering	-0.299	-0.313	-0.279	-0.364	-0.429	-0.429
Days to maturity	0.005	0.132	-0.510	-0.122	0.057	0.016
Number of capsule $plant^{-1}$	0.680*	-0.525	-0.452	-0.446	0.378	0.621
1000 Seed weight	-0.275	0.770**	0.603	0.626	-0.101	-0.243
Stem yield	0.969**	-0.220	-0.319	-0.229	0.914**	1.000

Table 4: Continue...

	No. of primary branches	Length of capsule	Days to 50% flowering	Days to maturity	No. of capsule $plant^{-1}$	1000 seed weight	Stem yield
Seed yield	0.128	0.266	-0.299	0.005	0.680*	-0.275	0.969**
Plant height at 30 DAS	0.333	0.408	-0.313	0.132	-0.525	0.770	-0.220
Plant height at 60 DAS	-0.036	0.393	-0.279	-0.510	-0.452	0.603	-0.319
Plant height at harvest	0.113	0.516	-0.364	-0.122	-0.446	0.626	-0.229
Dry matter production at 60 DAS	0.103	0.131	-0.429	0.057	0.378	-0.101	0.914**
Dry matter production at harvest	0.114	0.274	-0.429	0.016	0.621	-0.243	1.000
No. of primary branches	1.000	0.327	0.308	0.587	0.228	0.346	0.114
Length of capsule	0.327	1.000	-0.409	-0.229	0.306	0.361	0.274
Days to 50% flowering	0.308	-0.409	1.000	0.505	0.071	-0.204	-0.429
Days to maturity	0.587	-0.229	0.505	1.000	0.217	-0.130	0.016
No. of capsule $plant^{-1}$	0.228	0.306	0.071	0.217	1.000	-0.623	0.621
1000 seed weight	0.346	0.361	-0.204	-0.130	-0.623	1.000	-0.243
Stem yield	0.114	0.274	-0.429	0.016	0.621	-0.243	1.000

*p=0.05; ** p=0.01 level of significance

whereas DM_{60}DAS recorded a similar significant positive association with DM_{HARV} and CGR-31. DM_{HARV} and CGR-61 displayed comparably low yet significant positive correlations between themselves. Similar patterns of low yet significant positive correlations were recorded in the case of LAI with DM_{30}DAS, DM_{60}DAS, DM_{HARV} and R-31. An opposite trend was noticed in the case of the traits that are negatively correlated. None of the negative correlations among the traits were recorded to be significant. Yet, considerably high (but insignificant) negative correlations were recorded between P_{30}DAS and CGR-61, likewise, between P_{60}DAS and DM_{60}DAS, DM_{HARV}, as well as CGR-31, individually.

3.9. Inter-and intra-cluster distances

All 16 treatments were grouped into five clusters (about 20-unit distance) obtained from the mean values of the germplasms using squared Euclidean distance (Figure 2).

Table 5: Regression analysis among the various parameters of sesame influence the seed yield

Variable	Estimate	Std. error	t value	Pr (>|t|)
Intercept	-3354.56	476.91	-7.03	0.0004
Stem yield	9.00	0.16	5.19	0.0020
Plant height at 30 DAS	11.38	3.33	3.41	0.0143
Dry matter prod. At 60 DAS	2.26	1.72	1.32	0.2350
No. of primary branches	-16.36	11.37	-1.44	0.2003
Length of capsule	-97.40	36.79	-2.65	0.0382
Days to 50 % flowering	24.65	5.69	4.33	0.0049
Days to maturity	-13.96	3.68	-3.79	0.0091
Number of capsules	8.07	2.22	3.63	0.0110
1000 seed weight	26.29	17.67	1.49	0.1873

*R^2=0.9921

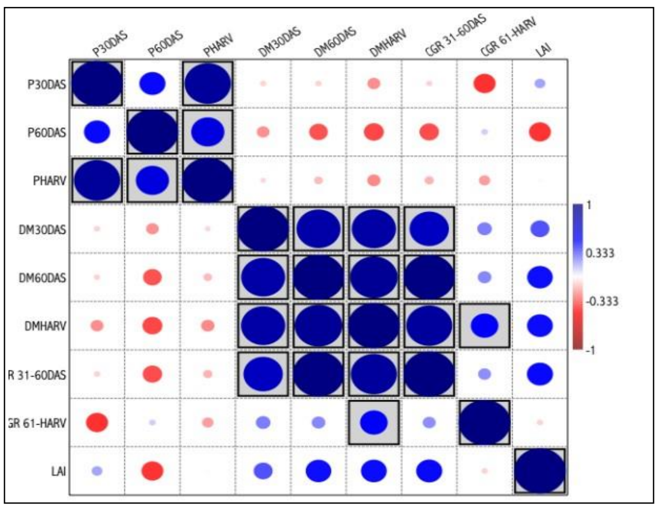

Figure 1: Association among traits explaining the best selection of component qualities for the genetic improvement in yield

S_1V_7 was the only treatment under cluster I. The cluster II consisted of three treatments, namely, S_1V_4, S_1V_2 and S_2V_2. The third cluster was comprised of S_1V_5, S_1V_6, S_2V_4 and S_1V_8. Likewise, S_1V_3, S_2V_3 and S_2V_7 are three treatments that formed the cluster IV. The cluster 5, which was the largest cluster among all the five, was comprised of S_2V_1, S_2V_6, S_2V_5, S_2V_8 and S_1V_1. The maximum intra-cluster distance was found in cluster V which was followed by cluster III, cluster III, cluster II, and cluster IV. No intra-cluster distance was recorded for cluster I since this cluster was comprised of a single treatment. The highest inter-cluster distance was detected between clusters I and V, tailed by clusters I and IV, whereas the least inter-cluster distance was detected between clusters IV and V.

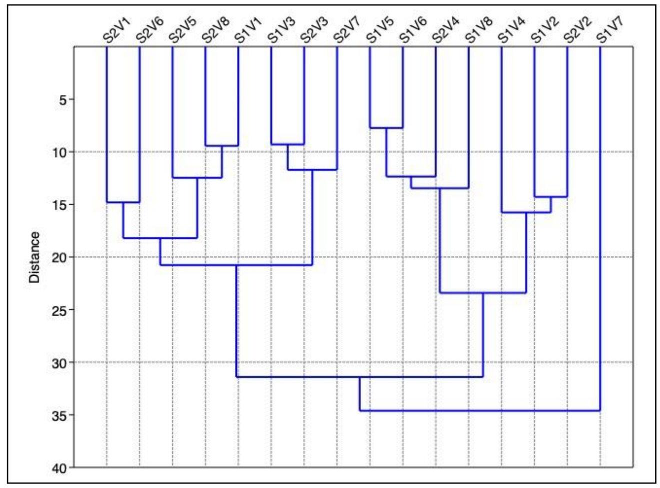

Figure 2: Dendogram explaining the influence of planting methods and varieties on growth, yield attributes and yield of sesame

4. CONCLUSION

From the aforesaid experiment, line sowing outperformed broadcasting and increased production by 7–9%. Improved high-yielding variety GT_2 outperformed other kinds, though variety GT_4 was fairly similar to GT_2. So, it was recommended to use line sowing to increase yield, even the broadcasting method of sowing had a greater benefit: cost ratio because cultivation costs were lower than line sowing. However, if production costs are reduced through mechanised agriculture, line sowing will be more profitable because it yields more than broadcasting.

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