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Growth and Yield of Summer Sesamum (*Sesamum indicum* L.), Dry Weight of Weeds and Weed Control Efficiency Influence by Different Row Spacing and Weed Management under South Gujarat Condition

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A B S T R A C T

A field experiment was conducted during summer season of 2016 at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari with Fourteen treatment combinations. Treatments were replicated thrice as per randomized block design with factorial concept. Significantly higher values of plant height (85.70 cm), number of leaves plant^{-1}(61.03), number of branches plant^{-1} (4.66), dry matter accumulation (15.26 g plant^{-1}), number of capsules plant^{-1} (57.00), number of seeds capsule^{-1}(62.45), length of capsule (3.19), seed yield (802 kg ha^{-1}) and straw yield (1731 kg ha^{-1}) were recorded with row spacing of 45 cm x 10 cm. Likewise, significantly maximum plant height (96.84 cm), number of leaves plant^{-1}(74.22), number of branches plant^{-1} (5.12), dry matter accumulation (17.86 g plant^{-1}), number of capsules plant^{-1} (68.20), number of seeds capsule^{-1}(70.80), length of capsule (3.47), seed yield (972 kg ha^{-1}) and straw yield (1924 kg ha^{-1}) were obtained with W_7 (Pendimethalin 1.0 kg ha^{-1} as PE *fb* quizalofop-P-ethyl 40 g ha^{-1} at 20 DAS *fb* H. W. at 40 DAS). Significantly lowest dry weight (377.60 kg ha^{-1}) of total weeds was noted under treatment S_1 (30 cm x 10 cm). In weed management treatments W_7 recorded markedly lower value of dry weight (270.52 kg ha^{-1}) of total weeds. Hence the crop sown with wider row spacing and weed management with integration of all methods showed favourable growth leads to higher yield of sesamum.

Introduction

Oilseeds are backbone of agricultural economy of India since long and considered as the second largest agricultural commodity in India after cereals (Yadav, 2011). Oilseeds are rich source of energy and nutrition. Edible oils and oil meals play pivotal role in solving the problem of malnutrition and securing the calorie nutrition for whole animal kingdom including human beings. Oilseed crops occupy an area of 28.05 million hectares with total production of 32.74 million tonnes and productivity 1168 kg ha^{-1} at national level during 2013-14 (Anonymous, 2016a). Sesamum alone occupies an area of 1.7 million hectare with the total production of 0.7 million tonnes and productivity of 426 kg ha^{-1} during 2013-14 among all the major oilseed crops (Anonymous, 2016b). Sesamum stands at third position in terms of total oilseed area and fourth in terms of total oilseed production in India. The average yield of sesamum is very low (274 kg ha^{-1}). Sesamum (*Sesamum indicum* L.) which is variously known as til, simsim, benised, gingelly, gergelim, *etc*. is one of the most important and extensively grown oilseed crops in India. The sesamum seeds are useful in confectionary and in religious rites. Being rich in protein, calcium, phosphorus and vitamin E, the sesamum cake are valuable cattle feed for farm and dairy animals. Sesamum "The queen of the oilseed crops" by virtue of the excellent quality of the oil, flavour, taste and softness. Its oil content generally varies from 46 to 52%. It is eaten as raw or either roasted or parched and mixed in many kitchen items. Commercially sesamum oil is used directly in pharmaceutical industries in plastering and manufacturing of soaps. Moreover, it is also used as hair oil, body lotion and fixative in perfume industries in cosmetics and adulterant with olive oil and "vanaspati ghee".

Growth, development and final yield of sesamum are mainly affected by the space available to plants; however, the precise and exact response will be species and cultivar specific. So, it is imperative to adjust plant population through row spacing which may help in avoiding excessive crowding and thereby enabling the plants to utilize these resources more effectively and efficiently resulting in increased production. Higher plant population per unit area beyond an optimum limit results in competition among the plants for natural resources, resulting into weaker plant and may cause severe lodging. Linear increase in grain yield has been reported with increase in plant density until other production factors become limiting (Norsworthy and Emerson, 2005). While, low density population produce more branches that carry fertile pods, thus prolonging the seed development phase. Weed competition in sesamum is maximum between 15 and 45 DAS (Duary. and Hazra, 2013). Weeds are one of the major constraints for the poor yield of sesamum crop as they compete with the crop plants for moisture, nutrients, light and space and 50-75% yield reduction cause by weeds in sesamum crop (Bhadauria *et al.*, 2012b). The weeds in many fields are capable of reducing yields by 79-80%, if left uncontrolled (Shaalan *et al.*, 2014).

Materials and Methods

In order to study the "summer sesamum (*Sesamum indicum* L.) Growth and yield as influenced by different row spacing and weed management under south Gujarat condition". A field experiment was conducted at College Farm, Navsari Agricultural University, Navsari throughout summer season of 2016. Navsari Agricultural University campus is geographically located at 20^0-57' N latitude and 72^0-54' E longitude at an altitude of 10 meters above the mean sea level. According to agro-climatic condition, Navsari is located in south Gujarat heavy rainfall zone-I (Agro-ecological situation-III). The climate of this zone is typically tropical, characterized by humid and warm monsoon with heavy rain, quite cold winter and fairly hot summer. The average annual rainfall of the tract is about 1500 mm. The soil of the experimental field was clayey in texture and showed low, medium and high rating for available nitrogen (197.26 kg ha^{-1}), phosphorus (30.93 kg ha^{-1}) and potassium (369.80 kg ha^{-1}), respectively. The soil was found slightly alkaline (pH 7.8) with normal electrical conductivity (0.36 dsm^{-1}).

The experiment was conducted with total fourteen treatment combinations consisting of two levels of row spacing *viz*., S_1: 30 cm x 10 cm, S_2: 45 cm x10 cm and seven levels of weed management practices *viz*., W_1: Weedy control, W_2: I. C. at 20 DAS *fb* H. W. at 40 DAS (Farmers practice), W_3: Pendimethalin 1.0 kg ha^{-1} as PE application, W_4:

Pendimethalin 1.0 kg ha^{-1} as PE *fb* quizalofop-P-ethyl 40 g ha^{-1} at 20 DAS, W_5: Oxadiargyl 90 g ha^{-1} as PE application, W_6: Oxadiargyl 90 g ha^{-1} as PE *fb* quizalofop-P-ethyl 40 g ha^{-1} at 20 DAS and W_7: Pendimethalin 1.0 kg ha^{-1} as PE *fb* quizalofop-P-ethyl 40 g ha^{-1} at 20 DAS and H. W. at 40 DAS, were evaluated with factorial randomized block design with three replications.

The investigation was carried out with the sesamum variety GT-3. Spraying of herbicide pre-emergence pendimethalin and post emergence quizalofop-P-ethyl was done at 2 DAS and 20 DAS respectively as per treatment. The observations for different characters were recorded at different periodical intervals. The statistical analysis of data was carried out through the procedure appropriate to the randomized block design with factorial concept of the experiment as described by Panse and Sukhatme (1967).

The observations for different characters were recorded at different periodical intervals. For biometric observation five plants were selected at random from each net plot and tagged for recording periodical growth and yield attributing parameters. The numbers of days required from the date of sowing to date at which 50 per cent plants have come to flowering were recorded as days to 50 per cent flowering for each treatment.

For recording dry matter accumulation by plant randomly five plants were dug out from the border area and expressed as g $plant^{-1}$. In case of weed dry matter accumulation the weed samples were collected from 1.0 m^2 area and expressed as g m^{-2} and finally at the time of harvest from entire net plot area of each plot and expressed as kg ha^{-1}. After removing the roots, the above ground plant parts and whole weed samples were first sun dried and finally oven dried at 65 ^{0}C for 72 hours up to constant dry weight.

The harvest index (%) was computed by using the formula suggested by Donald (1963) and recorded separately for each treatment.

$$\text{HI (\%)} = \frac{\text{Economical yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100$$

The weed control efficiency was calculated by using the following formula (Kondap and Upadhyay, 1985).

$$\text{WCE (\%)} = \frac{\text{DWC} - \text{DWT}}{\text{DWC}} \times 100$$

Where, DWC and DWT were the weed dry weight in control and treated plots, respectively.

Results and Discussion

Study on plant

Effect of row spacing

Wider row spacing S_2 (45 cm x 10 cm) produce significantly taller plant (85.70 cm), maximum number of leaves $pant^{-1}$ (61.03) and maximum number of branches $plant^{-1}$(4.66) over narrow spacing 30 cm x 10 cm (S_1). The probable reasons for higher plant height, more number of leaves and more number of branches $plant^{-1}$ might be due to relatively competition free environments prevail, hence more availability of nutrients, greater light interception, efficient utilization of soil moisture and space under lower degree of inter-plant competition. Almost similar findings were also reported by Ali *et al.*, (2005) at Faisalabad, Pakistan and Shekh *et al.*, (2014) at Junagadh. The significantly higher dry matter production $plant^{-1}$ (15.26 g $plant^{-1}$) was recorded under treatment S_2 (45 cm x 10 cm). The increase in plant vigour in terms of height, number of leaves and branches plant^{-1}, with wider row spacing was found to be useful in utilizing the radiant energy more effectively, ultimately lead to increased synthesis of carbohydrate and production of more dry matter plant^{-1}. The present result is close conformation with Hemalatha *et al.,* (1999) at Tirupati (A.P.) and Patel (2012) at S.D.A.U., Gujarat. Whereas, non-significant difference was observed in days to 50 per cent flowering due to different row spacing (Table 1). While, contradictory results reported in this regard by Haruna (2011) and Monpara and Vaghasia (2016). Significantly higher values for the yield attributing characters, *viz.,* number of capsules plant^{-1} (57), number of seeds capsule^{-1} (62.45), and length of capsule (3.19 cm) were recorded under treatment S_2 (45 cm x 10 cm). The better development of various yield attributes might be due to low degree of inter plant competition for moisture, nutrients, solar energy and more availability of resources for development of individual plant, reflecting in higher vegetative growth. As a result of better partitioning of photosynthates from source to sink, development of yield attributes was better under wide row spacing. This result was consistent with the results observed by Hemalatha *et al.,* (1999) at Tirupati (A. P.); Tahir *et al.,* (2012) at Faisalabad (Pakistan) and Shekh *et al.,* (2014) at Junagadh (Gujarat). Non-significant difference was observed in 1000 seed weight of sesamum due to different row spacing. That may be due to the fact that grains act as strong physiological reservoirs and rarely respond to the treatments like row spacing. The present result is in close conformation with Ghungarde *et al.,* (1992) at Parbhani; Ali *et al.,* (2005) at Faisalabad, Pakistan. While, Hemalatha *et al.,* (1999) Tirupati (A.P.); Shekh *et al.,* (2014) at Junagadh (Gujarat) and Monpara and Vaghasia (2016) at Amreli (Gujarat) reported contradictory results with respect to the 1000 seed weight which was significantly influenced by different row spacing. Significantly higher grain yield (802 kg ha^{-1}) and straw yield (1731 kg ha^{-1}) obtained under treatment S_2 (45 cm x 10 cm).It was due to the overall better growth performance and higher values of most of the yield attributes under wider row spacing resulted into significantly higher grain yield with treatment S_2. Better development of various growth parameters such as plant height, number of branches plant^{-1} and dry matter accumulation ultimately reflected into significantly higher straw yield under treatment S_2. It was probably due to optimum plant population per unit area which gave optimum yield per plant and lower plant competition. The wider row spacing improved individual plant yield and yield per unit area is the resultant of cumulative yield from individual plants per unit area. A narrow row spacing sown crops have more number of plants per unit area and reduction in yield per plant might not to be compensated with yield from more number of plants per unit area. These results are in agreement with those of Ali *et al.,* (2005) at Faisalabad, Pakistan. While, Hemalatha *et al.,* (1999) at Tirupati (A.P.); Shekh *et al.,* (2014) at Junagadh (Gujarat) and Prasannakumara *et al.,* (2014) at Dharwad reported contradictory results in this regard. Harvest index remained unaffected due to different row spacing (Table 2).

Effect of weed management

Treatment W_7 recorded the maximum plant height (96.84 cm) but remained statistically at par with treatments W_2 and W_4. Significantly the maximum number of leaves plant^{-1} (74.22) were recorded with treatment W_7 but it was statistically at par with treatment W_2. Significantly higher number of branches plant^{-1} (5.12) was observed with W_7, but it being statistically at par with W_2 and W_4. The maximum values of all the growth parameters in these treatments (W_7, W_2 and W_4) and lowest value in treatment W_1 (weedy control) might be due to the reasons that application of pendimethalin as pre-emergence gave better control of weeds from very beginning at an early stage and reduced early weed competition lead to more nutrient and soil moisture available to the crop which enhanced vegetative growth of sesamum. The results are in agreement with the findings of Svathi *et al.*, (2005) at Karaikal and Mathukia *et al.*, (2015) at Junagadh (Gujarat). Non-significant difference was observed in days to 50 per cent flowering due to various weed management treatments applied to sesamum. Significantly maximum dry matter production plant^{-1} (17.86 g plant^{-1}) was recorded with treatment W_7 but it was statistically at par with treatment W_2, W_4 and W_6 at 60 DAS.

Significantly the lowest dry matter plant^{-1} was produced in weedy control treatment (W_1) at all the stages of crop growth. This might be due to better growth of plants in terms of plant height, number of leaves and branches plant^{-1}, ultimately resulted in higher dry matter accumulation plant^{-1}. These results are in agreement with the findings of Mruthul *et al.*, (2015) (Table 2).

Table.1 Effect of different row spacing and weed management treatments on growth and Growth attributes of sesamum

Treatments	Plant height (cm)		Number of leaves plant^{-1}		Number of branches plant^{-1}		DMA (g plant^{-1})		Days to 50% flowering
	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	
Row spacing (S)									
S_1	71.50	76.69	60.86	56.38	4.19	4.31	10.09	13.68	38.57
S_2	81.32	85.70	65.56	61.03	4.49	4.66	10.90	15.26	39.33
S.Em. $\pm$	1.79	1.88	1.35	1.31	0.10	0.11	0.22	0.32	0.59
C.D. at 5%	5.20	5.47	3.92	3.81	0.28	0.31	0.63	0.94	NS
Weed management practices (W)									
W_1	54.46	59.83	40.33	36.00	3.86	3.77	9.09	12.73	36.50
W_2	86.73	92.71	72.52	67.68	4.66	4.87	11.31	15.04	37.27
W_3	71.77	76.10	65.77	60.10	3.86	4.06	10.60	13.66	38.82
W_4	84.41	90.08	69.13	65.80	4.69	4.79	10.97	14.11	40.81
W_5	65.87	69.70	51.08	47.92	4.16	4.43	9.84	13.30	38.91
W_6	79.29	83.13	63.90	59.23	4.25	4.39	10.68	14.60	38.98
W_7	92.34	96.84	79.72	74.22	4.92	5.12	10.98	17.86	41.36
S.Em. $\pm$	3.35	3.52	2.52	2.45	0.18	0.20	0.40	0.60	1.11
C.D. at 5%	9.73	10.23	7.33	7.13	0.52	0.57	1.17	1.76	NS
C.V. %	10.73	10.61	9.77	10.23	10.04	10.72	9.40	10.23	6.99
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table.2 Effect of different row spacing and weed management treatments on yield and Yield attributes of summer sesamum

Treatments	No. of capsules plant^{-1}	No. of seeds capsule^{-1}	Length of capsule (cm)	1000 seed weight (g)	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
Row spacing (S)							
S_1	51.70	56.80	3.00	2.99	735	1522	32.58
S_2	57.00	62.45	3.19	3.01	802	1731	31.74
S.Em. ±	1.20	0.99	0.05	0.04	16.78	44.96	0.45
C.D. at 5%	3.47	2.88	0.13	NS	48.79	130.72	NS
Weed management practices (W)							
W_1	43.40	52.25	2.61	2.89	504	1049	32.38
W_2	61.13	66.88	3.38	3.06	874	1894	31.63
W_3	49.48	55.70	2.89	2.97	703	1494	32.06
W_4	58.46	60.17	3.34	3.05	834	1811	31.59
W_5	47.73	53.47	2.83	2.91	681	1528	31.10
W_6	52.03	58.12	3.15	3.02	812	1683	32.72
W_7	68.20	70.80	3.47	3.10	972	1924	33.63
S.Em. ±	2.24	1.85	0.09	0.08	31.39	84.11	0.85
C.D. at 5%	6.50	5.38	0.25	NS	91.28	244.55	NS
C.V. %	10.07	7.60	6.84	6.29	10.01	12.67	6.44
Interaction	NS	NS	NS	NS	NS	NS	NS

Table.3 Dry weight of weeds and WCE % as influenced by different row spacing and weed Management treatments in summer sesamum

Treatments	Weed dry weight			Weed control efficiency (%)		
	At 20 DAS (g m^{-2})	At 40 DAS (g m^{-2})	At harvest (kg ha^{-1})	At 20 DAS	At 40 DAS	At harvest
S_1	13.90	26.44	377.60	-	-	-
S_2	14.53	32.65	431.43	-	-	-
S.Em. ±	0.28	0.62	12.48	-	-	-
C.D. at 5%	NS	1.80	36.29	-	-	-
W_1	19.24	52.30	771.92	0.00	0.00	0.00
W_2	16.01	22.75	282.75	16.78	56.49	63.37
W_3	13.28	32.76	443.88	30.99	37.36	42.50
W_4	12.32	20.81	323.78	35.94	60.21	58.05
W_5	14.85	35.62	432.00	22.83	31.89	44.04
W_6	13.66	24.67	306.73	29.02	52.82	60.26
W_7	10.16	17.90	270.52	47.21	65.77	64.96
S.Em. ±	0.52	1.16	23.35	-	-	-
C.D. at 5%	1.50	3.37	67.90	-	-	-
C.V. %	8.92	9.61	14.14	-	-	-
Interaction	NS	NS	NS	-	-	-

S_1: 30 cm x 10 cm, S_2: 45 cm x10 cm, W_1: Weedy control, W_2: I. C. at 20 DAS *fb* H. W. at 40 DAS (Farmers practice), W_3: Pendimethalin 1.0 kg ha^{-1} as PE application, W_4: Pendimethalin 1.0 kg ha^{-1} as PE *fb* quizalofop-P-ethyl 40 g ha^{-1} at 20 DAS, W_5: Oxadiargyl 90 g ha^{-1} as PE application, W_6: Oxadiargyl 90 g ha^{-1} as PE *fb* quizalofop-P- ethyl 40 g ha^{-1} at 20 DAS and W_7: Pendimethalin 1.0 kg ha^{-1} as PE *fb* quizalofop-P-ethyl 40 g ha^{-1} at 20 DAS and H. W. at 40 DAS.

The treatment W_7 recorded significantly higher values of yield attributing characters *viz.*, number of capsules plant^{-1} (68.20), number of seeds capsule^{-1} (70.80) and length of capsule (3.47 cm) of above parameters but it remained statistically at par with W_2 for numbers of seeds capsule^{-1}. While, in case of length of capsule it remained at par with treatment W_2 and W_4. However, the lowest values of above yield attributes were observed under the treatment W_1. This trend of results indicating least competition offered by weeds for nutrients and moisture at crucial growth stages under these treatments ultimately improved all yield attributes besides increased rate of N, P and K absorption as evident from nutrient uptake studies cumulatively helped the crop plants to produce more surface area for high photosynthetic rate as well as maximum translocation of photosynthates from source to sink, subsequently resulted in improvement of above yield attributes. Because of synergist effect among the yield attributes they benefited each other. However, significantly higher seed and straw yield (972 and 1924 kg ha^{-1}, respectively) recorded under treatment W_7 but remained at par with the treatments W_2, W_4 and W_6 in case of straw yield only. The remarkable increase in seed and straw yield under these treatments might be due to effective control of weeds, lower dry weight of weeds and higher weed control efficiency as well as lower weed index which cumulatively facilitated the crop to utilize more nutrients and water for better growth and development in terms of various growth attributing characters such as plant height, number of branches plant^{-1} and yield attributing characters. All the parameters showed positive and highly significant influence on seed and straw yield of sesamum. These findings are in accordance with those of Mathukia *et al.*, (2015) at Junagadh; Mruthul *et al.*, (2015) at Raichur. There was no significant effect of weed management treatments with respect to 1000 seed weight and harvest index (Table 2). The contradictory result was recorded in this regard by Mathukia *et al.*, (2015) at Junagadh (Gujarat) in case of 1000 seed weight and Mruthul *et al.*, (2015) at Raichur.

Study on weeds

Effect of row spacing

The effect of row spacing on dry weight of weeds at 20 DAS was found to be non-significant. While, the lowest dry weight of weeds was also found under narrow spacing treatment S_1 *i.e.* 30 cm x 10 cm at 40 DAS and at harvest (26.44 g m^{-2} and 377.60 kg ha^{-1}). That might be due to more number of plants per unit area in narrow row spacing lead to shading effect resulting from the crop canopy, limits availability of resources required for weed germination, emergence and growth. This effect is more pronounced in 30 cm x 10 cm row spacing. Weed biomass reduction at this period can be explained by the reduction in total incoming photosynthetic active radiation (PAR) reaching the ground and indicates that narrow inter-row spacing increased the competitiveness of the sesamum with weeds. These results are in line with those reported by Patel (2000) in sugarcane; Hussein *et al.*, (2008) in maize; Takim and Adereti (2012) in soybean and Bakht and Khan (2014) in tomato.

Effect of weed management

The dry weight of weeds recorded at 20, 40 DAS and at harvest were reduced significantly by all weed management treatments as compared to weedy control (W_1). Treatment W_7 recorded the lower dry weight of weeds (10.16 g m^{-2}, 17.90 g m^{-2} and 270.52 kg ha^{-1} at 20, 40 DAS and at harvest, respectively) but it was found at par with treatment W_4 at 40 DAS while, at harvest it was found at par with treatment W_2, W_6 and

W_4. This might be due to the combination of both cultural and chemical methods which was found to be more effective in suppressing the weed density as well as weed dry matter (Table 3). Various weed management treatments showed better weed control efficiency. The response of different weed management practices in term of weed control efficiency at 20 DAS was remained in order of $W_7 > W_4 > W_3 > W_6 > W_5 > W_2 > W_1$. However, in case of 40 DAS it was remained in order of $W_7 > W_4 > W_2 > W_6 > W_3 > W_5 > W_1$ and at harvest the order was $W_7 > W_2 > W_6 > W_4 > W_5 > W_3 > W_1$. The results have confirmed the findings of Mathukia *et al.*, (2015) and Mruthul *et al.*, (2015).

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