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RESEARCH ARTICLE

Enhancing the production potential of transplanted sesame (*Sesamum indicum* L.) under a semi-arid environment

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Abstract

Field experiments were conducted during the winter seasons of 2021 to 2022 at the Research farm of V.O. Chidambaranar Agricultural College and Research Institute, Killikulam, Tamil Nadu, Agricultural University, Tamil Nadu, to assess the suitable planting methods and optimize the age of seedlings to enhance the productivity and profitability of transplanted sesame. The experiment comprised nine treatment combinations having two planting methods (Ridge planting and Flat planting) and four ages of seedlings (12, 16, 20, and 24 days old seedling) along with line sowing (30 x 30 cm) as control were laid out in randomized block design(RBD) and replicated thrice. It may be inferred that ridge planting of 20 days sesame seedlings for transplanting practice gave significantly higher growth, yield parameters, and maximum yield *viz*., plant height (121.0 cm and 130.0 cm), LAI (4.16 and 4.26) and DMP (2765 kg ha^{-1} and 3010 kg ha^{-1}), Number of branches $plant^{-1}$ (9.1 and 9.8), number of capsules $plant^{-1}$ (93.4 and 96.0), Number of seeds per capsule (55.2 and 56.0), seed yield (892 kg ha^{-1} and 910 kg ha^{-1}) and B: C (2.59 and 2.65) as compared to all other treatment combinations. The findings emphasize the potential of this technique for enhancing the productivity of transplanted sesame, and it is profitable to the farmers of semi-arid regions of southern India.

Keywords

age of seedling; productivity; profitability; sesame; transplanting

Introduction

Sesame (*Sesamum indicum* L.), a member of the Pedaliaceae family, is a vital oilseed crop often referred to as the "Queen of Oilseeds." Renowned for its exceptionally high oil content, sesame thrives in tropical and subtropical regions. Environmental factors significantly impact its cultivation, shaping the crop's productivity. Globally, Myanmar, India, and China are the top three producers among the 22-leading sesame-producing nations (1). According to Food and Agriculture Organization (FAO) statistics, the total production from these prominent sesame-producing countries constitutes 92.6% of the global sesame production. India continues to be the biggest contributor, occupying over 40% of the world's sesame cultivation area and contributing 27% to global production (2). Despite having a large area under cultivation, India's overall production and productivity (431 kg ha^{-1}) is low compared to the global average of 512 kg ha^{-1} (3). The main reason for the

low productivity of sesame is cultivation in marginal and sub-marginal lands with poor agronomic management. Thus, agronomic practices such as tillage, planting methods, and transplanting of seedlings at the optimum age have a greater influence on crop performance and yield of sesame. Since transplanting in sesame is an innovative technology, selecting the proper age of seedlings for transplanting without sacrificing the yield of the direct sown crop is very important. The appropriate age of seedlings for transplanting is vital in enhancing growth and development, resulting in greater yield in a suitable environment (4). The yield of crops might be reduced when aged seedlings are used during transplanting because of the well establishment of crops during nursery conditions. The suitable seedling age for transplanting in the main field with saturated field conditions helps the seedlings withstand transplanting shock and continue to grow. Therefore, the current study aims to boost the production potential of transplanted sesame under semi-arid conditions.

Materials and Methods

Experimental site

An experiment was conducted in the Department of Agronomy at VOC Agricultural College and Research Institute, Killikulam (8°46' N latitude and 77°42' E longitude and at an altitude of 40 m above MSL), Tamil Nadu, India, during the *rabi* season of 2021-22 and 2022-23. The experimental site falls under India's Agro-climatic zone XI (East Coast plains and hills). The information on various meteorological aspects like maximum temperature 35.6 °C and 33.2 °C, minimum temperature 25.2 °C and 20.1 °C, relative humidity 60.4 % and 69.4%, rainfall 102 mm and 119.6 mm, average evaporation 6.9 mm and 5.1 mm day^{-1}, sunshine 6.9 hrs and 6.4 hrs and wind speed 4.3 and 5.1 km hr^{-1} prevailed during both years, respectively.

Experimental design and treatments

The experiments were laid out in RBD with nine treatments and three replications. Treatment details are as follows:

T_1: Line sowing with 30 × 30 cm

T_2: Ridge planting of 12 days old seedling

T_3: Ridge planting of 16 days old seedling

T_4: Ridge planting of 20 days old seedling

T_5: Ridge planting of 24 days old seedling

T_6: Flat planting of 12 days old seedling

T_7: Flat planting of 16 days old seedling

T_8: Flat planting of 20 days old seedling

T_9: Flat planting of 24 days old seedling

Soil characters of the experiment

The experimental site's topography was uniform and levelled. The soil was sandy clay loam. The soil characteristics are pH 7.8, EC 0.24 ds m^{-1}, and organic carbon(OC) 4.30 g kg^{-1}. It is low in available nitrogen (N) (238 kg ha^{-1}), medium in available phosphorus (P) (19 kg ha^{-1}), and high in available potassium (K) (290 kg ha^{-1}).

Crop management

The Sesame variety TMV 7 was selected for the experimental study. Raised beds measuring 2 m × 2 m and 15 cm in height were prepared. The top 10 cm layer of soil was removed, and seedlings were cultivated in a nursery medium composed of red earth, sand, and vermicompost in a 2:1:1 ratio. Drainage and irrigation channels were established to facilitate watering and excess water removal. Ridges were created with 45 cm spacing, and seedlings were transplanted on both sides of the ridges, maintaining a spacing of 30 × 30 cm. Ridges and furrows give the surface of the ground a wavy corrugated effect, like corduroy, and consist of linear ridges with shallow ditches between them, which would reduce the soil related problems and improve crop growth and yield. The recommended cultural practices and plant protection measures were taken as per recommendation during the experiments. The biometrics were recorded on five randomly selected plants from net plots of each treatment. Observations were recorded on growth attributes *viz.,* plant height, leaf area index, dry matter production, and yield characters like number of branches per plant, number of capsules per plant, number of seeds per capsule, seed yield and economics were worked out to assess the crop growth, yield, and economic feasibility of transplanted sesame.

Data analysis

The data was statistically analyzed for RBD (5). Wherever statistical significance was noticed, Critical Difference (CD) at 0.05 probability level was made out for comparison. Non-significant results were expressed as 'NS.

Results and Discussion

Growth attributes

The study revealed significant differences in growth attributes (Table 1) of transplanted sesame *viz*., plant height, leaf area index, and dry matter production among different planting methods and seedlings' age during both crop growth years (Fig. 1).

Table 1. Effect of different planting methods and age of seedlings on growth attributes of transplanted sesame

Treatments	Plant height at harvest (cm)		LAI		DMP at harvest (kg ha^{-1})	
	2021	2022	2021	2022	2021	2022
T_1	86.8	90.4	3.79	3.69	2145	2200
T_2	80.2	87.8	3.60	3.65	2020	2053
T_3	110.0	115.0	4.01	4.01	2610	2705
T_4	121.0	130.0	4.16	4.26	2765	3010
T_5	95.3	100.2	3.85	3.65	2240	2100
T_6	73.6	81.1	3.51	3.51	1895	1790
T_7	105.0	110.7	3.88	3.68	2120	2194
T_8	109.0	114.3	3.92	3.82	2485	2512
T_9	93.8	94.6	3.82	3.52	2270	2305
SE.d	1.48	2.81	0.04	0.08	37.86	47.46
CD(P=0.05)	3.15	5.97	0.09	0.16	80.26	100.62

Treatment details are given under Materials and methods.

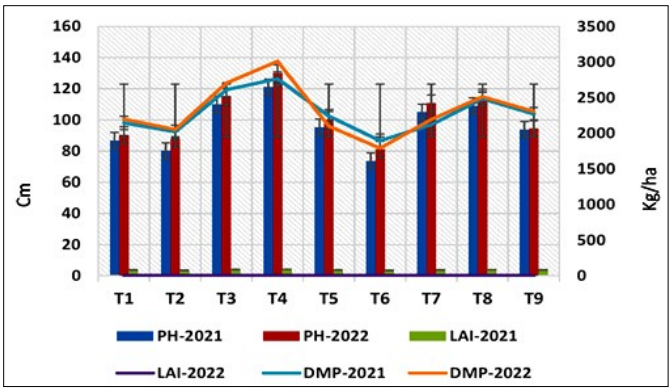

Fig. 1. Growth attributes of transplanted sesame during the *rabi* seasons.

Ridge planting of 20 days old seedlings (T_4) produced taller plants (121.0 cm and 130.0 cm), and it was followed by Ridge planting of 16 days old seedlings (T_3) (110 cm and 115 cm), and the shorter plants of 73.6 cm and 81.1 cm were perceived under flat planting of 12 days old seedling (T_6) during both the years of 2021 and 2022. Ridge planting of 20-day-old seedlings showed 64.4 and 60.3 % higher plant height than flat planting of 12-day-old seedlings during 2021 and 2022. Even in ridge planting, 20-day-old seedlings exposed (10 and 13.04 %) and (30 and 20%) higher plant heights than 16- and 24-day-old seedlings, respectively, during both years. The increased plant height may be attributed to competition for space, moisture, nutrients, and light, a phenomenon influenced by the annidation process. This competition likely intensified phototropism, resulting in taller plants (6). Ridge planting of 20-day-old seedlings (T_4) recorded a higher Leaf Area Index (LAI) (4.16 and 4.26) than other treatments during both years. Even in the ridge planting method, transplanting 20-day-old seedlings recorded a 15.5 and 16.7 percent higher LAI than the 12-day-old younger seedlings (T_2). This may be because better root growth helped through increased cell division and elongation, leading to an increased photosynthetic rate. Subsequently, it increases LAI. Higher root biomass and photosynthetic activity were the main reasons for producing more leaf area. Similar analogous were also reported by (7).

Ridge planting of 20-day-old seedlings (T_4) recorded higher dry matter production (2765 kg ha^{-1} and 3010 kg ha^{-1}) than other treatments during both years. This finding is similar to the findings of an experiment, which noted the highest soil moisture and growth attributes with the ridge and furrow method (8). The cause of maximum dry matter production was transplanted with 20 days old age seedlings, which may be traced to the significant increase in morphological parameters such as plant height, leaf area index, and thus dry matter accumulation. This effect might be due to timely transplanting at the proper age of the seedling. The significant positive impact on various growth attributes can be attributed to the optimal stage of crop transplantation, which ensures better early survival by maintaining the transpiration balance and meeting energy requirements. Transplanting 20-day-old seedlings led to superior growth in sesame, including increased plant height, LAI, and dry matter accumulation, compared to other treatments involving seedlings aged 12, 16 and 24 days. Transplanting of 12 days younger seedlings shows lower growth attributes than line sowing and different ages of seedlings. This may be due to poor root development and its effect on the vegetative growth attributes. Transplanting 16- and 24-day-old seedlings also shows lower growth attributes than 20-day-old seedlings. So, the optimum age of seedling for transplanting sesame is 20 days old seedling with proper planting methods enhances the growth attributes of transplanted sesame in the semi-arid regions.

Yield traits and yield

The seed yield of transplanted sesame was enhanced by various yield aspects such as the number of branches plant^{-1}, number of capsules plant$^{-1,}$ and number of seeds capsule^{-1}. All these yield characters were significantly influenced by different planting methods and age of seedlings (Table 2).

Table 2. Effect of different planting methods and age of seedlings on yield attributes and yield of transplanted sesame

Treatments	No. of branches plant^{-1}		Number of capsules plant^{-1}		No. of seeds capsule^{-1}		Seed yield (kg ha^{-1})	
	2021	2022	2021	2022	2021	2022	2021	2022
T_1	7.2	7.5	61.4	63.4	40.2	41.0	685	698
T_2	6.3	6.8	55.8	58.2	36.8	37.2	657	670
T_3	8.4	8.7	89.4	92.0	53.8	55.0	830	841
T_4	9.1	9.8	93.4	96.0	55.2	56.0	892	910
T_5	7.9	8.3	69.2	71.4	46.6	46.2	745	760
T_6	5.6	6.1	48.6	52.8	34.6	34.8	640	682
T_7	8.0	8.4	80.4	82.6	49.2	50.4	721	735
T_8	8.2	8.9	83.2	85.2	50.8	51.2	790	808
T_9	6.6	7.0	57.8	59.4	42.6	42.8	764	774
SE.d	0.13	0.16	1.50	1.74	1.02	1.07	14.62	13.48
CD(P=0.05)	0.27	0.65	3.18	3.69	2.16	2.26	31.00	28.58

Treatment details are given under Material and methods.

The maximum number of branches per plant (T_4) (9.1 and 9.8) was recorded with ridge planting of 20 days seedlings, which were significantly higher by 62.5 and 60.6 %, over flat planting of 12 days seeding(T_6) during both years. The number of capsules per plant is one of the major yield's parameters in transplanted sesame, which directly contributes to the yield. A higher number of capsules per plant was recorded under T_4–Ridge planting of 20 days seedlings (93.4 and 96.0) during both years of study. The number of capsules plant^{-1} was 92.1 and 81.8 percent higher when ridge planting and seedlings were transplanted at 20 days than flat planting of 12 days old seedlings during both years. The highest number of capsules per plant in this treatment can be attributed to the optimal planting method and the appropriate age of sesame seedlings at transplantation. These factors enhanced plant growth, dry matter accumulation, and ultimately the yield attributes, leading to maximum yield. The ridges and furrow planting method created a favourable environment, producing the maximum capsules in sesame plants. These findings agree with other studies that reported maximum yield attributes of ridge and furrow compared to the flat land method (8, 9). Treatments with different ages of seed-

lings showed a significant effect on the number of seeds capsule$^{-1,}$ and it was higher in seedlings transplanted with the age of 20 days compared to the younger seedlings. This might be because of better accumulation of photosynthates during vegetative growth and their effective translocation during the reproductive phase to the sink. This is in accordance with the findings of other studies, which reported that the reduction in the number of sesame plant density, sub-branches, and number of capsules per plant increased, it might be due to increased dry matter accumulation and lack of competition between plants (10,11). However, the younger seedlings needed more days to flower due to the seedlings' slow development in the main field. Conversely, optimally grown seedlings necessitated significantly less time to transition from the vegetative to the reproductive phase, resulting in increased This is followed by the findings of a previous study(12).

The results showed that ridge planting of 20 days old seedlings (T_4) recorded significantly higher seed yield (892 kg ha^{-1} and 910 kg ha^{-1}), followed by ridge planting of 16 days old seedlings (T_3) (830 kg ha^{-1} and 841 kg ha^{-1}) and the lower yield (T_6) (640 kg ha^{-1} and 682 kg ha^{-1}) was produced in line sowing during both the years (Fig. 2.). The highest grain yield (892 kg ha^{-1} and 910 kg ha^{-1}) was recorded by ridge planting of 20 days seedlings (T_4) and was higher by 7.4 and 8.20% over T3, respectively, during 2021 and 2022. Sowing of sesame on ridge and furrow significantly promoted yield attributes and yield compared to flat planting. The experiment's findings showed that seedlings were influenced positively when 20 days old age and produced significant maximum seed yield ha^{-1} over the rest of the age-old seedlings, *i.e.,* 12, 16 and 24 days. This increase in the seed yield was due to a considerable improvement in photosynthetic activity observed when sesame was transplanted at 20 days old seedling, and this could be attributed to the substantially higher yield contributing characters. These results align with a previously conducted study (13). It was further reported that higher productivity of crops is achieved by optimum age and number of seedlings (14). As per the observations of a previous study, transplanting shock occurred due to transplanting extremely young or aged seedlings, which take additional days to establish in the field (15). Hardiness occurred with the increased age of seedlings while transplanting, and it was less with the incidence of pests and diseases, leading to higher stalk yield than the conventional method. This result was consonant with another previously conducted study (16).

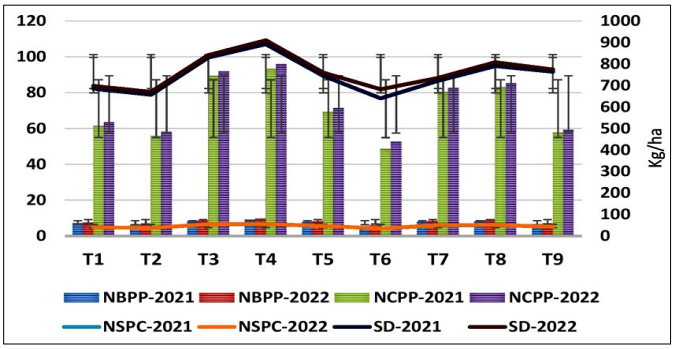

Fig. 2. Yield attributes and yield of transplanted sesame during the *rabi* seasons.

Economics

The net return earned out of the transplanting technique in sesame confessed that Ridge planting of 20 days seedling (T_4) recorded a higher net return of Rs. 57,509 ha^{-1} and Rs. 59,139 ha^{-1} during both years due to minimum usage of seed rate and higher seed yield and economic return achieved under transplanting (Table 3). It was followed by sesame transplanting with ridge planting of 16 days seedlings (T_3) and fetched a net return of Rs. 50,995 ha^{-1} and Rs. 52,154 ha^{-1} during both years. The B: C ratio of the transplanting technique in sesame proclaimed that Ridge planting of 20 days old seedlings (T_4) recorded higher B: C ratios of 2.59 and 2.65 during both years. Further, it was followed by sesame transplanting with ridge planting of 16 days seedlings (T_3) and fetched the B: C ratio of 2.41 and 2.44, respectively. It revealed that the transplanting system of cultivation was more profitable than the conventional method of sowing. This might be the reason for greater crop productivity, resulting in higher net returns and B: C ratio. Fig. 3 represents the economics of different planting methods and age of seedlings of transplanted sesame.

Table 3. Effect of different planting methods and age of seedling on the economics of transplanted sesame

Treatments	Net Income (Rs. ha^{-1})		B:C ratio	
	2021	2022	2021	2022
T_1	34513	35878	1.95	1.96
T_2	34199	32834	1.92	1.91
T_3	50999	52154	2.41	2.44
T_4	57509	59139	2.59	2.65
T_5	42074	43649	2.16	2.21
T_6	27500	31910	1.69	1.80
T_7	36005	37475	1.91	1.94
T_8	43250	45140	2.09	2.14
T_9	40520	41570	2.02	2.05

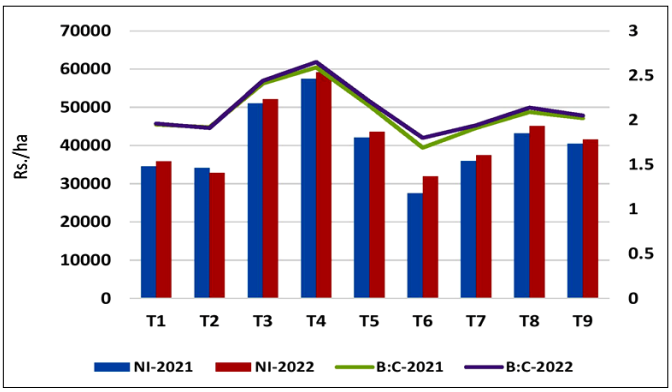

Fig. 3. Economics of different planting methods and age of seedlings of transplanted sesame.

Conclusion

From the field study, it could be concluded that ridge planting of 20 days seedlings of transplanted sesame rec-

orded higher growth and yield attributes and yield of crops under the semi-arid region of Agro-climatic zone XI (East coast plains and hills) of India during both the years of experiment (2021 and 2022). Ridge planting is more advantageous than flat planting or line sowing. However, farmers can opt for flat planting with seedlings of the optimal age rather than line sowing to achieve better returns when labor is scarce. Transplanting sesame seedlings at the optimal age of 20 days results in superior crop growth and yield, offering greater profitability for farmers compared to traditional practices like line sowing or broadcasting. Thus, transplanting 20-day-old seedlings using the ridge planting method improves productivity and is profitable for farmers in the semi-arid regions of India.

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Authors' contributions

JB, NSK, MA, TS and AF participated in literature search, collection of data conceptualization, visualization, review, supervision, analysis, writing-original draft, review and editing; NSK and MS participated in review and editing. All authors have read and agreed to the published version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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