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Influence of farming practices on different growth contributing parameters of soybean (*Glycine max* L.)

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Abstract
A field experiment was conducted during *kharif* season of 2023 at Agronomy Division, College of Agriculture, and Pune to study the influence of farming practices on growth contributing parameters of soybean (*Glycine max* L.). The experiment was laid out in randomized block design having five treatments with four replications. The treatments comprised T_1 - Farmers practice, T_2 - MPKV Recommended package of practices, T_3 - Organic farming, T_4 - Natural farming, T_5 - Climate resilient farming. The soil of experimental site was clay loam in texture. The findings of present investigation revealed that all growth contributing parameters *viz.,* plant height (87.37 cm), plant spread (64.01 cm), number of branches plant^{-1} (7.35), number of functional trifoliate leaves plant^{-1} (14.05), leaf area plant^{-1} (26.70 dm^2), number of root nodules plant^{-1} (22.00), fresh weight of root nodules plant^{-1} (559 mg), dry weight of root nodules plant^{-1} (256 mg), dry matter plant^{-1} (63.32 g), AGR (1.51 g day^{-1}), CGR (66.98g m^2 day^{-1}) were significantly higher recorded in Climate resilient farming (T_5).

Keywords: Soybean, farming practices, growth, dry matter plant^{-1}, AGR, CGR

1. Introduction
The Green Revolution, while instrumental in addressing India's food scarcity, inadvertently introduced significant environmental concerns. The excessive use of synthetic inputs, intensive agriculture, and monoculture systems have led to soil degradation, water pollution, and biodiversity loss. This environmental toll has raised serious questions about the long-term sustainability of current agricultural practices. In response, there has been a growing interest in alternative approaches that prioritize ecological balance and minimize the use of harmful chemicals. Natural farming, rooted in Indian traditions and informed by modern ecological understanding, offers a promising solution. By emphasizing biodiversity, soil health, and resource conservation, natural farming seeks to create a more sustainable and resilient agricultural system.

The adoption of natural farming practices in India has the potential to address several critical challenges. Firstly, it can help mitigate the environmental impacts of conventional agriculture, reducing reliance on chemical fertilizers and pesticides. Secondly, natural farming can enhance soil health, improve water retention, and promote biodiversity, thereby increasing the resilience of agricultural systems to climate change. Thirdly, by reducing input costs and increasing on-farm resource utilization, natural farming can improve the economic viability of smallholder farms, empowering rural communities. Finally, natural farming can contribute to the production of high-quality, organic soybean, which is increasingly sought after by consumers concerned about health and sustainability.

However, the transition to natural farming presents several challenges. Farmers may face initial yield declines during the conversion period, as they adjust to new practices and allow their soil to recover from previous chemical inputs. Additionally, the certification process for organic products can be costly and time-consuming, potentially limiting market access for small-scale producers. To overcome these obstacles, governments and support organizations can play a crucial role in providing farmers with training, technical assistance, and access to markets for organic products.

With the above facts, the urgent need for sustainable and resilient agricultural practices necessitates a careful evaluation of existing methods and the exploration of innovative alternatives. Natural farming, with its emphasis on ecological balance and resource conservation, offers a promising approach to address the challenges posed by conventional agriculture. By promoting biodiversity, improving soil health, and reducing reliance on harmful chemicals, natural farming can contribute to a more sustainable and equitable food system for India and beyond. Soybean, a versatile legume with high protein and oil content, plays a pivotal role in India's agricultural landscape. However, the country's reliance on traditional farming methods and the challenges posed by climate change necessitates a critical evaluation of existing practices and the exploration of innovative solutions.

2. Materials and Methods

The field experiment was carried out during *kharif* season of 2023 at Agronomy Division, College of Agriculture, Pune (Maharashtra). The experimental field was clay loam in texture with moderately alkaline in reaction (pH 8.51). The soil was very low in available nitrogen (112.89 kg ha^{-1}), very low in available phosphorous (6.12 kg ha^{-1}) and very high in available potassium (379.9 kg ha^{-1}) as well as moderately high in organic carbon content (0.66%). The present experiment was laid out by the using of randomized block design (RBD) with four replications. The treatments were consisting of different farming practices i.e. T_1 - Farmers practice, T_2 - MPKV Recommended Package of practices, T_3 - Organic Farming, T_4 - Natural farming and T_5 - Climate Resilient Farming. The plot size was 6.40 m x 6.30 m. Seed rate for soybean was 75 kg/ha and row to row spacing was maintained at 45 cm. The recommended dose of fertilizers was 50:75:45 kg N: P_2O_5: K_2O basal were applied as basal.

2.1 Treatment details

Treatments	Package of practices for *kharif* soybean
T_1: Farmers practice	Preparatory tillage: one ploughing, harrowing and seed bed preparation.
	Sowing: Sowing after onset of monsoon.
	Nutrient management: Broadcasting of two bags of 10:26:26 N, P_2O_5 and K_2O per acre at the time of sowing.
	Application of two foliar sprays of 19:19:19 @ 2% up to flowering stage.
	Weed management: one hand weeding + one application of Imazathpyr 10% SL @ 1.00 L/ha.
	Plant Protection
	Application of 2 alternate sprays of Chlorpyriphos 50% + Cypermethrin 5% EC @ 2ml and Chlorantraniliprol 18.5 SC @ 0.40 ml/L of water at 15 days interval from 30 DAS.
	Spraying of Tebuconazole 0.1%
T_2: MPKV Recommended Package of Practices	Soil: Medium deep, well drained
	Preparatory tillage: One ploughing, two harrowing with good seed bed preparation.
	Sowing: After onset of monsoon at *vapsa* condition. (15th June to 1st week of July)
	Spacing: 45 x 5 cm upto 4.00 cm depth of sowing.
	Seed rate: 75 kg/ha
	Seed treatment: Carboxin 37.5%+ thiram 37.5% DS 3 g followed by Azoxystrobin 2.5% + Thiophanate methyl 11.25%+ Thiamethoxam 25% FS 10 ml / kg of seed followed by MPKV consortium of *Rhizobium*, PSB and KMB @ 25 ml /kg seed.
	Nutrient management: Application of GRDF: 10 t FYM ha^{-1} + (50:75:45 kg ha^{-1} N, P_2O_5 and K_2O).
	Weed management
	One hoeing at 15-20 DAS + One hand weeding + post emergence application of herbicide Propaquizafop 2.5% + Imazathpyr 3.75% ME @ 40 ml/10 L of water.
	Water management:
	Protective irrigation is given if dry spell is occurred at branching (30-35 DAS), flowering (45-50 DAS), pod development (70-75 DAS).
	Plant Protection
	Spraying of Tebuconazole 10% + Sulphur 65% WG @ 0.25%.
	Erection of bird perches @ 25 per ha.
	Installation of pheromone traps @5 traps/ha (from initiation of flowering)
	Spraying of Imidacloprid 48% MS @ 2.5 ml/ 10 L of water (30 days after sowing)
	Spraying of *Azadirachtin* 10000 ppm @ 1 ml/L of water (45 days after sowing)
	Spraying of Profenophos 50EC @ 20 ml/ 10 L of water (60 days after sowing).
	Spraying of *Sl*NPV@ 250LE or 2ml/L of water (75 days after sowing)
	Spraying of Chlorantraniliprole 9.30% + Lambda cyhalothrin 4.60% ZC @ 4ml/ 10 lit of water (90 days after sowing).
T_3: Organic Farming	Soil: Medium deep, well drained.
	Preparatory tillage: one ploughing + two harrowing with good seed bed preparation.
	Sowing: After onset of monsoon at *vapsa* condition.
	Seed rate: 75 kg/ha.
	Spacing: 45 x 5 cm.
	Seed treatment with MPKV consortium of *Rhizobium*, PSB and KMB @25 ml/kg seed followed by seed treatment of *Trichoderma (+)* @ 5g /kg seed.
	Nutrient management: Application of FYM @ 10 t ha^{-1} with *Trichoderma (+)* 2.5 kg / acre (by mixing with 50 kg moist FYM), vermicompost @ 3.5 t ha^{-1} and phosphate rich organic manure (PROM) @ 200 kg ha^{-1}.
	Water management
	Protective irrigation will be applied if dry spell is occurred at branching (30-35 DAS), flowering (45-50 DAS), pod development (70-75 DAS)
	Weed management
	One hoeing at 20 DAS + one hand weeding at 30 DAS. Mulching of weed/crop residues and uprooting of weeds.

	Plant protection
	Spraying of Dashparni ark @ 5L ha^{-1} in 200 L of water (30 days after sowing)
	Spraying of *Metarrhizium anisopliae* @ 2 g/L of water (45 days after sowing)
	Installation of pheromone traps @5 traps/ha (from initiation of flowering)
	Spraying of *Sl*NPV@ 250LE or 2ml/L of water (60 days after sowing)
	Spraying of *Bacillus thuringiensis* @2 g/L of water (75 days after sowing).
	Primary tillage operations followed by zero tillage to succeeding crop.
	Soil application of Ghanjeevamrit @ 2000 kg ha^{-1} during sowing.
	Mixed cropping system broadcasting of jowar and maize @ 12 kg ha^{-1}
	Water management: Irrigation scheduled for maintaining *vapsa.*
	Seed treatment, Nutrient management and Plant protection: Seed treatment of Beejamrit and drying of seeds in shade.
	After sowing mulching of crop residues.
	If there will be no rainfall, after sowing application of 500 L ha^{-1} Jeevamrit with first two irrigations.
T$_4$: Natural Farming	**Foliar spray of Jeevamrit**
	12.5 L ha^{-1}Jeevamritha in 250 L of water at 21 days after sowing (DAS)
	19 L ha^{-1}Jeevamritha in 300 L of water at 45 DAS
	25 L ha^{-1}Jeevamritha in 375 L of water at 65 DAS
	37.5 L ha^{-1}Jeevamritha in 375 L of water at 80 DAS
	Spraying of 7.5 L ha^{-1} Sour Buttermilk in 250 L of water at 90 DAS.
	Spraying of Dashparni ark (30 days after sowing)
	Spraying of deshi cow urine @ 2 per cent @ 20 ml/L of water. (55 days after sowing).
	Spraying of Bramhastra @ 20 ml/L of water (90 days after sowing).
T$_5$: Climate Resilient	Land preparation: Primary tillage *viz*., ploughing, harrowing, preparation of BBF (Broad Bed and furrow)
	Seed treatment: Carboxin 37.5% + thiram 37.5% DS 3 g followed by Azoxystrobin 2.5% + thiophanate methyl 11.25% + thiamethoxam 25% FS 10 ml / kg of seed followed by MPKV consortium of *Rhizobium*, PSB and KMB @25 ml /kg seed.
	Sowing: After onset of monsoon. Sowing of soybean on BBF
	Nutrient management
	Soil application of *Trichoderma (+)* @ 2.5 kg/acre (by mixing with 50 kg moist FYM).
	Application of chemical fertilizers as per soil test.
	Application of FYM @10 t ha^{-1} (Basal application)
	Water management: Protective irrigation is given through sprinkler system if dry spell is occurred.
	Weed management
Farming	One hoeing at 20 DAS + one hand weeding at 30 DAS + Post emergence application of herbicide Propaquizafop 2.5% + Imazathpyr 3.75% ME @ 40 ml/10 L of water. (as per the situation).
	Mulching of weed/crop residues.
	Plant protection: Erection of bird perches @25 per ha.
	Spraying of Tebuconazole 10% + Sulphur 65% WG @ 0.25%.
	Installation of pheromone traps @ 5 traps/ha (After initiation of flowering).
	Spraying of *Azadirachtin* 10000 ppm @ 3 ml/lit of water (30 days after sowing).
	Spraying of *Sl*NPV@ 250LE or 2ml/lit of water (45 days after sowing).
	Spraying of *Bacillus thuringiensis* @ 2 g/lit of water (60 days after sowing)
	Spraying of EPN @ 2 g/lit of water (75 days after sowing).
	Spraying of Chlorantraniliprol 9.30% + Lambda cyhalothrin 4.60% ZC @ 4ml/ 10 lit of water (90 days after sowing).

2.2 Growth Studies
The growth contributing parameters *viz.,* Plant height (cm), plant spread (cm), number of branches plant^{-1}, number of functional trifoliate leaves plant^{-1}, leaf area plant^{-1} (dm^2) and dry matter plant^{-1} (g) were observed and recorded at 28, 42, 56, 70, 84 DAS and at harvest. AGR (Absolute growth rate) and CGR (Crop growth rate) were calculated by standard formula. The days to 50% flowering were calculated by observing all plants in each net plot and counting the days it took for half of the plants in each plot to reach full bloom. The number of root nodules per plant was determined by randomly selecting one plant from each net plot at 50% flowering, carefully uprooting it, washing the roots, and counting the active nodules. The fresh weights of these nodules were recorded. These nodules were dried in an oven at 60 °C ± 5 °C temperature till constant weight and dry weight of nodules were obtained. The maturity of the crop in each net plot was determined by observing the leaves for yellowing and drying. Once the grains in the pods became tough, the plants were considered physiologically mature. The days to maturity were calculated from the time of sowing to the point when all plants in a net plot were completely dried.

3. Result and Discussion
3.1 Growth studies (Table 1)
3.1.1 Plant height (cm)
Among different farming practices, Climate resilient farming (T$_5$) noticed significantly higher plant height at harvest (87.37 cm) over the remaining farming practices. Whereas, the minimum plant height of soybean was registered in Natural farming (T$_4$). The maximum plant height in Climate resilient farming (T$_5$) might be due to optimized nutrient management, water conservation, pest control strategies, and optimal plant growth and development. The Climate resilient farming (T$_5$) showed promising results, indicating its effectiveness because this farming practice included the combined application of recommended dose of fertilizers with organic manures. Comparable findings were observed by Khaim *et al.* (2013) [4] and Ghodke *et al.* (2018) [2].

3.1.2 Plant spread (cm)
Climate resilient farming (T$_5$) recorded maximum plant spread at the time of harvest (63.51 cm) in comparison to other farming practices under research trial. The superior performance of climate-resilient farming (T$_5$) in terms of plant spread could be

ascribed to the availability of nutrients. Conversely, the poor performance of Natural farming (T_4) might be associated with lower nutrient accessibility and increased weed competition leading to reduced plant spread.

3.1.3 Number of branches plant^{-1}

Climate resilient farming (T_5) recorded a significantly higher number of branches plant^{-1} at harvest (7.35). While Natural farming (T_4) marked the lowest number of branches plant^{-1}.This may be a result of enhanced nutrient availability and uptake by soybean, which secured a greater number of branches plant^{-1}. Similar results were recorded by Ghodke *et al.* (2018) [2] and Meena *et al.* (2023) [6].

3.1.4 Number of trifoliate functional leaves plant^{-1}

Among the various farming practices, Climate resilient farming (T_5) registered a significantly maximum number of trifoliate functional leaves plant^{-1} at 84 DAS (12.20). These findings possibly caused by the sufficient availability of plant nutrients through the combined use of recommended chemical fertilizers and organic manures. The results are in agreement with Morya *et al.* (2018) [7], Sharifi *et al.* (2018) [10] and Singh *et al.* (2020) [11].

3.1.5 Leaf area plant^{-1}(dm^2)

The Climate resilient farming practice (T_5) produced a significantly larger leaf area plant^{-1} at 84 DAS (23.67 dm^2) over all the farming practices. This result may a consequence the sufficient amount of plant nutrients supplied through the combined application of synthetic and organic fertilizers at vegetative growth stages, which led to a greater number of functional leaves, which results in a large size and area of leaves. These findings are similar with the findings of Sharifi *et al.* (2018) [11].

3.1.6 Number of root nodules plant^{-1}, fresh weight of nodules plant^{-1}and Dry weight of nodules plant^{-1} (mg) (Table 2)

Significantly higher number of root nodules plant^{-1} (22.00) was remarked in Climate resilient farming (T_5) and it was found at par with the University recommended package of practices (T_2) (20.25), Organic farming practice (T_3) (20.00) and Natural farming (T_4) (19.50). The lower number of root nodules plant^{-1} were recorded in Farmers practice (T_1). The maximum number of root nodules plant^{-1} in the Climate resilient farming (T_5) and University recommended package of practice (T_2) might be due to the adequate availability of multinutrient and increased microbial interactions in the root zone through the application MPKV consortium. These outcomes are in line with Devi *et al.* (2013) [1] and Ghadage *et al.* (2020) [13]. The Climate resilient farming also found at par with Organic farming (T_3) and Natural farming (T_4) probably because of less accessibility of nitrogen to plants, which increased the number of root nodules in both T_3 and T_4 farming practices to fulfil the nitrogen requirement of soybean through atmospheric nitrogen fixation. A similar finding was observed by Joshi *et al.* (2023) [3]. The significantly highest fresh weight (559 mg) and dry weight (256 mg) of root nodules plant^{-1} was recorded in Climate resilient farming (T_5); it was found at par with all remaining farming practices except Farmers practice (T_1). The significantly higher fresh and dry weight of root nodule plant^{-1} in Climate resilient farming may be due to the inoculation of the MPKV consortium, which enhances the functions of Rhizobium and phosphate-solubilizing bacteria, thereby promoting root growth and nitrogen fixation. The results align closely with the observations of Singh *et al.* (2020) [11] and Meena *et al.* (2023) [6].

3.1.7 Dry matter plant^{-1} (g)

Climate resilient farming practice (T_5) registered significantly maximum dry accumulation plant^{-1} over remaining farming practices at harvest (63.32 g plant^{-1}). The minimum accumulation of dry matter plant^{-1} of soybean was determined in Natural farming (T_4). The dry matter production plant^{-1} had been consistently greater in Climate resilient farming (T_5), which might be an outcome of integrated application of organic and inorganic fertilizers. Organic manures released nutrients slowly, while chemical fertilizers fulfilled the nutrient demand readily and prolonged the availability of macro and micro nutrients, which aided in the acceleration of multiple metabolic processes such as photosynthesis and energy transfer reactions and promoted plant growth. Microorganisms like *Rhizobium* and PSB have the accelerated symbiotic biological N-fixation process, which leads to greater dry matter accumulation. Similar results were noted by Morya *et al.* (2018) [7].

3.1.8 Days to 50% flowering and maturity (Table 2)

The data showed in Table 2 elaborates that, the mean number of days required to 50% flowering and maturity of soybean were not impacted substantially because of various farming practices. The mean number of days to 50% flowering were 46.70 and mean number of days to physiological maturity was 97.20. Numerically highest number of days to 50 percent flowering (47.25) and maturity (99.25) were recorded in Climate resilient farming (T_5). However, the minimum number of days to 50 percent flowering (45.50) was noted in treatment of Farmers practice (T_1) and the number of days to physiological maturity was 95.25 noted in treatment of Farmers practice (T_1) and Organic farming (T_3).

3.1.9 Absolute growth rate (g day^{-1}) (Table 3)

The result in the Table 3 illustrated that, the mean absolute growth rate of soybean was significantly affected ascribed to different farming practices under study at all growth stages. The mean absolute growth rate was higher at 28-42 DAS and decreased thereafter up to 84- at harvest. Numerically, maximum absolute growth rate was noticed in Climate resilient farming (T_5) during each growth stages of soybean over other farming practices. It was 1.51, 0.74, 0.67, 0.51, 0.35 g day^{-1} at 28-42, 42-56, 56-70, 70-84 DAS and at 84 DAS - at harvest, respectively. However, this farming practice was found at par with the University recommended package of practices (T_2) at 42-56 DAS, 56-70 DAS and at 70-84 DAS. At 56-70 DAS Climate resilient farming was at par with Farmers practice (T_1). Whereas, the lower growth rate was recorded in Natural farming (T_4) during all growth phases of soybean. Similar result was recorded by Ronanki *et al.* (2018) [9].

3.1.10 Crop growth rate (g m^{-2} day^{-1}) (Table 4)

The Figures indicate that, the mean crop growth rate of soybean was differed significantly at all growth stages of soybean. The highest crop growth rate was recorded at 28-42 DAS and declined thereafter up to 84 DAS - at harvest. Numerically, the highest crop growth rate was recorded in Climate resilient farming (T_5) at all growth stages of soybean over rest of the farming practices. It was 66.98, 32.78, 29.58, 22.70 and 15.55 g m^{-2} day^{-1} at 28-42 DAS, 42-56 DAS, 56-70DAS, 70-84 DAS and 84 DAS- at harvest, respectively. However, this farming practice was found at par with the University recommended package of practices (T_2) at 42-56 DAS, 56-70 DAS and at 70-

84 DAS. At 56-70 DAS Climate resilient farming was at par with Farmers practice (T_1). While, the lowest crop growth rate was recorded under Natural farming (T_4) at all growth stages. The result was in consonance with Meena *et al.* (2016) [5].

Table 1: Growth contributing parameters of soybean as influenced periodically due to different farming practices

Tr. No.	Framing practices	At harvest				84 DAS	
		Plant height (cm)	Plant Spread (cm)	Number of Branches Plant^{-1}	Dry matter Plant^{-1} (g)	Number trifoliate functional leaves plant^{-1}	Leaf area plant^{-1} (dm^2)
T_1	Farmers Practice	80.17	58.07	4.50	47.13	8.65	16.44
T_2	MPKV Recommended Package of Practices	84.72	59.95	5.70	56.39	10.00	20.70
T_3	Organic Farming	77.65	56.29	4.20	39.27	7.35	13.81
T_4	Natural Farming	75.98	55.11	4.15	35.63	6.90	11.51
T_5	Climate Resilient Farming	87.37	63.51	7.35	63.32	12.20	23.67
S.E.M. ±		0.66	0.51	0.36	0.63	0.42	0.70
C.D. at 5%		2.04	1.58	1.12	1.95	1.30	2.17
General Mean		81.18	58.59	5.18	48.35	9.02	17.22

Table 2: Number of root nodule plant^{-1}, fresh weight and dry weight of root nodule plant^{-1} of soybean at 42 DAS, Days to 50% flowering and days to maturity as influenced due to different farming practices

Tr. No.	Farming practices	At 42 DAS			Days to 50% flowering	Days to maturity
		No. of root nodules plant^{-1}	Fresh weight of root nodules plant^{-1} (mg)	Dry weight of root nodules plant^{-1} (mg)		
T_1	Farmers Practice	17.50	287	151	45.50	95.25
T_2	MPKV Recommended Package of Practices	20.25	440	220	47.50	98.75
T_3	Organic Farming	20.00	460	233	47.00	96.50
T_4	Natural Farming	19.50	447	208	46.25	96.25
T_5	Climate Resilient Farming	22.00	559	256	47.25	99.25
S.E.M. ±		0.83	41	16	1.00	1.07
C.D. at 5%		2.55	126	48	NS	NS
General Mean		19.85	438	213	46.70	97.20

Table 3: Absolute growth rate of soybean as influenced periodically due to different farming practices

Tr. No.	Farming practices	Absolute growth rate (g day^{-1})				
		28-42	42-56	56-70	70-84	84-At harvest
T_1	Farmers Practice	1.26	0.56	0.51	0.28	0.18
T_2	MPKV Recommended Package of Practices	1.36	0.67	0.61	0.48	0.21
T_3	Organic Farming	1.18	0.40	0.31	0.23	0.15
T_4	Natural Farming	1.10	0.36	0.24	0.20	0.12
T_5	Climate Resilient Farming	1.51	0.74	0.67	0.51	0.35
S.E.M. ±		0.04	0.06	0.06	0.06	0.03
CD at 5%		0.12	0.17	0.17	0.17	0.08
GM		1.28	0.54	0.47	0.34	0.20

Table 4: Crop growth rate of soybean as influenced periodically due to different farming practices

Tr. No.	Farming practices	Crop growth rate (g m^{-2} day^{-1})				
		28-42	42-56	56-70	70-84	84-At harvest
T_1	Farmers Practice	56.11	25.00	22.62	12.34	8.06
T_2	MPKV Recommended Package of Practices	60.39	29.57	27.25	21.43	9.33
T_3	Organic Farming	52.61	17.62	13.61	10.37	6.78
T_4	Natural Farming	49.04	15.99	10.59	9.08	5.48
T_5	Climate Resilient Farming	66.98	32.78	29.58	22.70	15.55
S.E.M. ±		1.74	2.48	2.46	2.51	1.18
CD at 5%		5.36	7.65	7.59	7.74	3.62
GM		57.03	24.19	20.73	15.18	9.04

4. Conclusion

The research findings demonstrate that Climate Resilient Farming significantly outperforms other farming practices in terms of plant growth and development. It exhibits higher plant height, spread, number of branches, leaves, and root nodules, leading to greater dry matter accumulation and leaf area. This superior performance is attributed to its optimized nutrient management, water conservation, and pest control strategies. The study highlights the effectiveness of Climate Resilient Farming in enhancing soybean yield and resilience.

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