



# Using Biochemical and Growth Parameters to Assess Soybean Yield Potential

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## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

This study, conducted in 2022 at the All India Coordinated Research Project on Soybean Dharwad, aimed to evaluate the yield potential of ten soybean genotypes, including three checks, using biochemical and growth parameters. Employing a randomized block design, the study assessed variations in chlorophyll content, which was highest in genotypes DLSb 3, DSb 34, and DSb 23.

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Significant differences among genotypes were observed in absolute growth rate (AGR), crop growth rate (CGR), relative growth rate (RGR), and net assimilation rate (NAR). Notably, DSb 34 and DLSb 5 exhibited the highest AGR and CGR at 60-90 days after sowing (DAS), while RGR was most pronounced in DSb 39 at 30-60 DAS. NAR peaked at 60-90 DAS, with DLSb 1 showing the highest values. Yield component analysis identified DLSb 5 and DSb 34 as the top-yielding genotypes, with significant variations in the number of pods per plant among the genotypes. These findings highlight key traits for breeding higher-yielding soybean varieties and offer valuable insights for future research and practical applications in crop improvement.”

**Keywords:** Chlorophyll; yield; soybean.

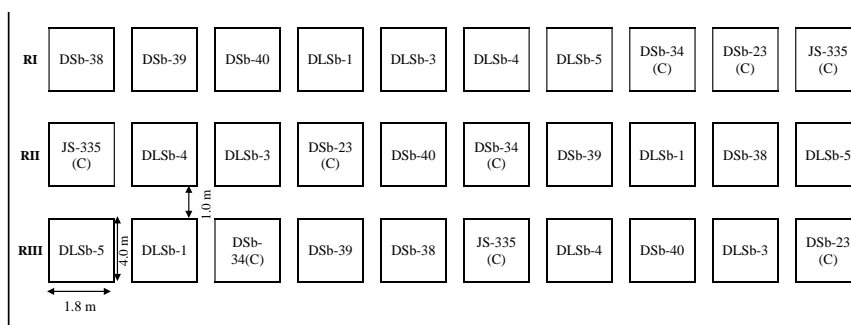
## 1. INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) is a legume crop belonging to the family Fabaceae and the subfamily Papilionaceae. It is an important pulse as well as an oilseed crop. Soybean is considered the king of beans due to its high protein and oil content in the seed which is approximately 40% and 20%, respectively. In India, 11.44 million hectares (m ha) area is under soybean cultivation with production and productivity of 12.04 million tonnes (m t) and 1052 kg ha<sup>-1</sup> respectively [1]. The major soybean-growing states in India are Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Karnataka and Gujarat. The area, production and productivity of soybean in Karnataka are 0.43 m ha, 0.44 m t and 1055 kg ha<sup>-1</sup> respectively [2]. Variations in dry matter accumulation and pod production among different genotypes can be attributed to factors such as crop growth rate (CGR), net assimilation rate (NAR) and relative growth rate (RGR). Optimal leaf area index (LAI) and net assimilation rate (NAR) in a plant may result in higher biological yield and seed yield [3]. The lower yield of soybean, despite its status as a stable and economically viable *khariif* crop, poses a major challenge for soybean cultivation. The availability of high-yielding and stable soybean genotypes suitable for different agro-climatic regions is a significant constraint. Crop yield is a

complex trait influenced by various genetic, biochemical and growth factors. The existence of uncertain constraints, such as lower sink demand, lead to a significant gap in achieving critical yield levels, resulting in the stagnation of genetic yield potential.

## 2. MATERIALS AND METHODS

The present investigation was conducted at All India Coordinated Research Project on Soybean, Main Agriculture Research Station, University of Agricultural Sciences, Dharwad. The experimental material comprised of ten soybean genotypes including three checks collected from AICRP on Soybean, Dharwad. Seven soybean genotypes were DSb 38, DSb 39, DSb 40, DLSb 1, DLSb 3, DLSb 4 and DLSb 5. Additionally, three checks, namely DSb 23, DSb 34 and JS 335 were included in the study. The field experiment was laid out in randomized block design and three replications as per the plan of the experiment. The gross plot size was 7.2 m<sup>2</sup> and net plot size was 4.8 m<sup>2</sup>. The plants were sown with inter-row spacing 30 cm and intra-row spacing 10 cm. The recommended dose of fertilizer and manure was applied as per package of practice for soybean with nitrogen, phosphorus and potassium @ 40:80:25 kg ha<sup>-1</sup> in the form of urea, DAP and MOP, respectively as top dressing.



**Fig. 1. Plan of experimental layout**

### 3. RESULTS AND DISCUSSION

#### 3.1 Performance of Soybean Genotypes for Biochemical Parameter

The performance of different soybean genotypes for biochemical parameter is presented in Table 1.

##### 3.1.1 Chlorophyll content

Chlorophyll content in soybean genotypes varied throughout the growth period. At 30 days after sowing (DAS), DLSb 3 had the highest chlorophyll content, DSb 34 had the highest chlorophyll *b* content and DLSb 34 had the highest total chlorophyll content. At 60 DAS, the genotypes were similar for chlorophyll *a* content except DLSb 4, which had the lowest chlorophyll content, chlorophyll *b* content and total chlorophyll content. DSb 34 had the highest chlorophyll *b* content and total chlorophyll content at 60 DAS. At 90 DAS, DLSb 5 and DSb 34 had the highest chlorophyll *a* content, DSb 38 had the highest chlorophyll *b* content and DSb 23 had the highest total chlorophyll content. DSb 38 had the lowest chlorophyll *a* content and chlorophyll *b* content and DSb 34 had the lowest total chlorophyll content at 90 DAS. The total chlorophyll content in all soybean genotypes increased between 30 and 60 days after sowing (DAS), but then gradually decreased as the plants approached maturity. This is consistent with the findings of Patel [4] and Betzelberger et al. [5] who found a positive correlation between chlorophyll content and yield.

#### 3.2 Performance of Soybean Genotypes for Growth Parameters

##### 3.2.1 Absolute Growth Rate (AGR)

Variation in AGR was significant among the genotypes during the growth stages, as detailed in Table 2. The absolute growth rate gradually increased with crop age and reached its peak during 60 to 90 DAS. The maximum AGR was observed at 60-90 DAS in all genotypes and at this stage highest AGR of 0.5871 g day<sup>-1</sup> was recorded by DSb 34 which was on par with DLSb 5 (0.5809 g day<sup>-1</sup>). The minimum AGR was recorded in genotype DSb 40 (0.4967 g day<sup>-1</sup>) on par with DSb 38 (0.5065 g day<sup>-1</sup>) and DSb 23 (0.5141 g day<sup>-1</sup>). The higher light interception exhibited in DSb 34 and DLSb 5 between 60 to 90 DAS, led to an increased photosynthetic rate and dry matter production, which, in turn, increased the AGR. The present findings are in

agreement with Deokar et al. [6] and Malek et al. [7] who reported that larger LAI as well as increased AGR at all growth stages were identified as essential traits for a high-yielding soybean genotype.

##### 3.2.2 Crop Growth Rate (CGR)

Throughout the growth stages, significant variation in CGR was observed among the genotypes as indicated in Table 2. The crop growth rate gradually increased with crop age and reached its peak during 60 to 90 DAS. The maximum CGR was observed at 60-90 DAS in all genotypes and at this stage highest CGR of 19.57 g m<sup>-2</sup> day<sup>-1</sup> was recorded by DSb 34 which was on par with DLSb 5 (19.36 g m<sup>-2</sup> day<sup>-1</sup>). The minimum CGR was recorded in the genotype DSb 40 (16.55 g m<sup>-2</sup> day<sup>-1</sup>) on par with DSb 38 (16.88 g m<sup>-2</sup> day<sup>-1</sup>) and DSb 23 (17.14 g m<sup>-2</sup> day<sup>-1</sup>). DSb 34 and DLSb 5 had the highest crop growth rate (CGR) between 60 and 90 days after sowing (DAS), while DSb 40 had the lowest. This was because DSb 34 and DLSb 5 had higher LAI values and light interception during that period. The higher LAI values and light interception led to increased photosynthetic rate and dry matter production, which in turn increased the CGR. A higher CGR was observed after the flowering stage in soybean genotypes Pedersen and Lauer, [8]. However, the CGR decreases after reaching its maximum value until maturity due to leaf ageing and abscission and there was a positive correlation between crop growth rate (CGR) and grain yield per plant. The present findings are in agreement with Dogra et al. [9] and Varsha et al. [10] who reported the same.

##### 3.2.3 Relative Growth Rate (RGR)

Significant differences in RGR were observed among soybean genotypes throughout the growth period (Table 2). The highest RGR occurred at 30-60 DAS in DSb 39 (0.0555 g g<sup>-1</sup> day<sup>-1</sup>) which was on par with DSb 34 (0.0554 g g<sup>-1</sup> day<sup>-1</sup>) and DLSb 1 (0.0553 g g<sup>-1</sup> day<sup>-1</sup>), while DSb 40 had the lowest (0.0526 g g<sup>-1</sup> day<sup>-1</sup>). RGR decreased with the age of crop. The decrease in RGR values between 60 DAS to harvest which attributed to a reduction in chlorophyll content and senescence of leaves. At 60 to 90 DAS, the Relative growth rate (RGR) was higher in DLSb 1 which was the low-yielding genotype and the lowest RGR was recorded in DSb 40 which was the fourth high-yielding genotype. A genotype with a high RGR does not necessarily produce a high yield. The present findings are in agreement

with Malek et al. [7] who reported that there is no relation between RGR and seed yield. Relative growth rate (RGR) declined with increasing age in all genotypes and it decreased rapidly from 60 to 90 DAS till physiological maturity due to the senescence of leaves and a reduction in SCMR which can lead to a decrease in photosynthetic rate and total dry matter. Salam et al. [11] suggested that RGR declines at later growth stages (reproductive stage) due to excessive mutual shading, as LA (leaf area) is at its maximum during this period and the increased number of old leaves could have lowered the photosynthetic efficiency. Hamid et al. [12] reported that the sharp decline in RGR during the reproductive stage was likely due to the increased demand for assimilates by the growing seed fraction. A similar decline in RGR with crop age has been reported by Tandale and Ubale [13] and Vyas and Khandwe [14].

### 3.2.4 Net Assimilation Rate (NAR)

There was a significant difference in NAR among the soybean genotypes throughout the crop growth period as presented in Table 2. At 60-90 DAS the highest NAR was recorded in DLSb 1 ( $0.0557 \text{ g dm}^{-2} \text{ day}^{-1}$ ) which was on par with DSb 34 ( $0.0545 \text{ g dm}^{-2} \text{ day}^{-1}$ ) and DSb 38 ( $0.0545 \text{ g dm}^{-2} \text{ day}^{-1}$ ) and minimum was recorded in genotype DSb 39 ( $0.0473 \text{ g dm}^{-2} \text{ day}^{-1}$ ) which was on par with JS 335 ( $0.0479 \text{ g}$

$\text{dm}^{-2} \text{ day}^{-1}$ ). The NAR was a maximum between 60 and 90 DAS. The soybean genotypes showed significant variation for net assimilation rate (NAR) from 30-60 DAS to 60-90 DAS. NAR increased from 30-60 DAS to 60-90 DAS. At 60 to 90 DAS, NAR was higher in DLSb 1, while the lowest NAR was recorded in DSb 39. Rajput and Shrivastava [15] reported genotypic differences in to NAR in soybean. The results are consistent with the findings of Deokar et al. [6].

## 3.3 Performance of Soybean Genotypes for Yield Components

### 3.3.1 Yield (q/ha)

The data on seed yield of the soybean genotypes is presented in Table 3. It has shown that the seed yield among the genotypes varied significantly. The highest seed yield, 31.21 q/ha, was recorded by the genotype DLSb 5, followed by DSb 34 (29.34 q/ha) and the lowest seed yield (18.83 q/ha) was recorded by the genotype DLSb 1.

### 3.3.2 Number of pods per plant

The data on the number of pods per plant are presented in Table 3, revealing variation among soybean genotypes. Notably, the genotype DLSb 5 recorded the highest number of pods per plant (63.20), while the lowest count (44.07) was observed in genotype DLSb 1, which was comparable to DLSb 4 (45.47).

**Table 1. Mean performance of soybean genotypes for chlorophyll content ( $\text{mg g}^{-1}$  fresh wt) at 30, 60 and 90 DAS**

Genotype	30 DAS			60 DAS			90 DAS		
	Chlorophyll			Chlorophyll			Chlorophyll		
	a	b	Total	a	b	Total	a	b	Total
DSb 38	1.144	0.508	1.651	1.720	1.079	2.800	0.933	1.169	2.102
DSb 39	1.267	0.527	1.794	1.660	0.893	2.553	1.531	0.913	2.445
DSb 40	1.217	0.614	1.831	1.666	0.888	2.554	0.962	0.424	1.386
DLSb 1	1.141	0.504	1.645	1.628	0.761	2.389	1.816	0.544	2.360
DLSb 3	1.346	0.534	1.880	1.714	0.990	2.704	1.130	0.746	1.876
DLSb 4	1.142	0.336	1.478	1.465	0.648	2.113	1.504	0.837	2.342
DLSb 5	1.264	0.573	1.838	1.734	1.128	2.862	1.847	0.261	2.108
DSb 34 (C)	1.237	0.676	1.913	1.742	1.201	2.942	1.847	0.242	2.090
DSb 23 (C)	1.181	0.519	1.700	1.655	0.685	2.340	1.820	1.037	2.857
JS 335 (C)	1.189	0.560	1.748	1.721	1.088	2.809	1.359	0.991	2.351
Mean	1.212	0.535	1.747	1.670	0.936	2.606	1.474	0.716	2.191
SEm±	0.036	0.016	0.053	0.050	0.046	0.096	0.099	0.038	0.097
CD(P=0.05)	0.109	0.048	0.157	0.150	0.136	0.286	0.295	0.112	0.288

**Table 2. Absolute growth rate (AGR), Crop growth rate (CGR), Relative growth rate (RGR) and Net assimilation rate (NAR) in soybean genotypes at 30-60 DAS and 60-90 DAS**

Genotype	AGR (g day <sup>-1</sup> )		CGR (g m <sup>-2</sup> day <sup>-1</sup> )		RGR (g g <sup>-1</sup> day <sup>-1</sup> )		NAR (g dm <sup>-2</sup> day <sup>-1</sup> )	
	30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS	30-60 DAS	60-90 DAS
	DSb 38	0.3880	0.5065	12.93	16.88	0.0552	0.0240	0.0497
DSb 39	0.4148	0.5679	13.82	18.93	0.0555	0.0249	0.0471	0.0473
DSb 40	0.3937	0.4967	13.12	16.55	0.0526	0.0231	0.0428	0.0524
DLSb 1	0.3671	0.5299	12.24	17.66	0.0553	0.0258	0.0505	0.0557
DLSb 3	0.4046	0.5235	13.49	17.45	0.0543	0.0238	0.0463	0.0524
DLSb 4	0.3919	0.5241	13.06	17.47	0.0541	0.0243	0.0492	0.0530
DLSb 5	0.4477	0.5809	14.92	19.36	0.0546	0.0239	0.0432	0.0491
DSb 34 (C)	0.4275	0.5871	14.25	19.57	0.0554	0.0249	0.0476	0.0545
DSb 23 (C)	0.3948	0.5141	13.16	17.14	0.0531	0.0237	0.0506	0.0528
JS 335 (C)	0.4304	0.5574	14.35	18.58	0.0551	0.0239	0.0465	0.0479
Mean	0.4060	0.5388	13.53	17.95	0.054	0.0242	0.0473	0.0519
SEm±	0.0063	0.0115	0.21	0.38	0.005	0.0005	0.0011	0.0015
CD(P=0.05)	0.0188	0.0340	0.62	1.13	0.001	0.0014	0.0033	0.0044

**Table 3. Mean performance of soybean genotypes for yield components**

Genotype	Pods/Plant	Yield (q/ha)
DSb 38	47.07	22.08
DSb 39	47.93	26.69
DSb 40	55.20	27.68
DLSb 1	44.07	18.83
DLSb 3	55.33	28.68
DLSb 4	45.47	23.76
DLSb 5	63.20	31.21
DSb 34 (C)	57.27	29.34
DSb 23 (C)	52.40	26.78
JS 335 (C)	51.67	25.12
Mean	51.96	26.01
SEm±	3.14	1.68
CD P=(0.05)	9.35	4.99

The soybean genotypes had significant differences in the number of pods per plant. DLSb 5 had the highest number of pods per plant which significantly gave higher seed yield, followed by DSb 34. DLSb 1 and DLSb 4 had the lowest number of pods per plant, with no significant difference between these two genotypes. The number of pods per plant is a major contributor to grain yield. Oz et al. [16] observed significant positive correlations between seed yield and the number of pods per plant. The result was by the findings of Ali et al. [17].

#### 4. CONCLUSION

In the present study, ten soybean genotypes were evaluated for biochemical and growth

parameters to identify key determinants of soybean yield. The results revealed significant variation among the genotypes across all studied parameters. The genotype DSb 34 exhibited the highest chlorophyll content, absolute growth rate (AGR), crop growth rate (CGR), net assimilation rate (NAR), and seed yield, followed by genotype DLSb 5. Conversely, the lowest values for all parameters were recorded in genotype DSb 40. These findings suggest that biochemical and growth parameters, including chlorophyll content, AGR, CGR, and NAR, are critical determinants of soybean yield. Therefore, these parameters could serve as effective selection criteria for developing high-yielding soybean varieties.

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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