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# EVALUATION OF ELITE SOYBEAN VARIETIES FOR SUITABILITY IN CONTINGENT SUMMER SEED PRODUCTION

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## Abstract

To assess the soybean varieties for suitability in seed production during the summer season, the experiment comprising seven elite varieties was laid out in R.B.D. design. The varieties MAUS 612 and MACS 1460 were promising in growth and yield attributes. The seed yield was significantly high in MAUS 612 (1863 kg/ha). The yield reduction over the average yield in Kharif was less in MAUS 612 (39.90%), MACS 1520 (40.44%) and MACS 1460 (41.20%) compared to the remaining varieties, showed their yield stability in changed growing season. MACS 1460 (19.57 kg/day/ha) and MAUS 612 (19.17 kg/day/ha) showed high GPE, while MAUS 612 (0.86) and MACS 1460 (0.80) were most promising in SYI and were found remunerative over others. Studies have shown a positive correlation between physiological traits and yield. Similarly, these two varieties were promising in terms of the quality of seed produced. Hence, MAUS 612 and MACS 1460 were suitable for contingent seed production in the summer.

## Introduction

Soybean (*Glycine max* [L.] Merrill) is a globally accepted legume-oilseed crop cultivated in diverse climatic conditions. Since its discovery as a food grain, its use has increased for food, feed, fodder, and biofuel. Due to its multiple uses, it is considered a wonder crop (Bagale 2021). Apart from this, Soybean plants fix 80-100 kg/ha of atmospheric nitrogen into the soil (Griebsh *et al.* 2020), reducing dependence on nitrogen fertilizers and enhancing soil organic matter, which improves the growth and productivity of subsequent crops (Jensen *et al.* 2012). In India, this crop is cultivated on an area of about 11.8 million hectares yearly, producing 11.87 million metric tons of soybean with a productivity of 1 metric ton per hectare (SPOA 2023). Madhya Pradesh, Maharashtra, and Rajasthan are the leading soybean-producing states of India, contributing about 90-95% of the total soybean area (Prajapat *et al.* 2014). This crop is widely grown in Maharashtra state, contributing an area of 33-35% of the soybean in India. The area under this crop is mainly distributed in the Vidarbha, Marathwada, Western Maharashtra and Khandesh regions of Maharashtra state, which have a diverse climatic condition posing a series of significant effects on the soybean crop production from sowing to harvest. This crop is grown in the Kharif season as a rainfed crop. But many of the times, harvesting coincides with heavy return monsoon in September, leading to the deterioration of the quality of the seeds produced and showing vivipary, fungal infection to seed, and continuous drying and wetting of seed, leading to loss of viability of the seed. Often, this leads to a shortage of soybean seeds and burdens seed-producing agencies. Keeping the above in view, the present study aimed to evaluate soybean varieties for off-season quality seed production to meet the seed requirement in the ensuing Kharif season.

## Materials and Methods

Field experiments were conducted during two consecutive summer seasons (January to April) of 2021 and 2022 at an experimental research farm of Agharkar Research Institute, Pune, India. The climatic condition of the site is characterized by a tropical climate with hot and dry summer

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from February to May, hot and humid from June to September and mild winter from October to January. The average annual rainfall is 500 to 750 mm. During the study period, the minimum temperature ranged from 12.60 to 22°C and the maximum from 28 to 38.75°C from January to April. The experiment was laid out in randomized block (R.B.D.) design, with three replications, and each replication consisted of seven elite soybean varieties which have been recently released for cultivation in the different agro-climatic conditions of India *viz.,* MACS 1520, MACS 1460, MACS 1188, KDS 726, KDS 753, MAUS 612 and AMS MB 5-18. The crop was sown on 25$^{th}$ January in both the years when the temperature started to rise above 18-20°C. The crop was sown in a net plot size of 3.6 × 5 m with a 45 × 5 cm planting geometry. The crop was raised following the standard package of practices and harvested manually after maturity. The data on biometric observations were recorded on randomly selected five plants. The seed yield per plot was converted to yield per hectare, and the harvest index (%) and seed index (g) were determined. The grain production efficiency (GPE) in terms of the number of days required to produce the seed yield was determined as per the formula given by Prajapat *et al*. (2014). The sustainability yield index (SYI) was worked out using the formula given by Singh *et al*. (1990). The data on normalized difference vegetation index (NDVI), leaf chlorophyll concentration (SPAD), canopy temperature depression (CTD) and relative leaf water content (RWC) was recorded as per the standard protocol given by Turner (1981), Crusiol *et al*. (2017). However, the data on the quality characters of the seed produced was recorded in terms of germination percentage by ISTA (2013), seedling vigour index I and II as suggested by Abdul-Baki and Anderson (1973), mean emergence time by Ellis and Roberts (1980), field emergence and field emergence index by Maguire (1962) of the produced seed, germination rate index (Al-Mudaris 1998) and electrical conductivity of the seed. Pearson's correlation coefficients were used to test the association between yield and physiological traits. The economics of the treatments were calculated in terms of gross returns, net returns and benefit-cost ratio. The data were analysed using standard variance techniques given by Gomez and Gomez (1984).

**Results and Discussion**

The data on the growth attributes in Table 1 revealed that the flowering and maturity of the varieties under study were different and were reduced by 1-2 days and 1-5 days, respectively, compared to the regular kharif season. This reduction might be due to the rise in the atmospheric temperature and long daylight period compared to the Kharif season, as soybean is a thermophilic-short day and highly photoperiod-sensitive plant (Hu and Wiatrak 2012). The plant height was significantly higher in MACS 1188 (65.50 cm) over the rest of the varieties under investigation and was closely followed by KDS 726 (61.63 cm). This might have resulted due to varietal intrinsic characters, growth hormonal response and its quantitative trait with pleiotropic effect and influenced by genotype, plant hormones and environmental conditions (Ma *et al*. 2019). The variety MAUS 612 was promising for the number of branches (3.50), internodes (12) and pod clusters (15) per plant, and was followed by MACS 1188 (3.33), MACS 1460 (3.0) and AMS MB-5-18 (2.67) for number of branches and AMS MB 5-18 (11) for number of internodes per plant. The number of clusters observed on every node on the plant stem might be cultivar-specific rather than the growth habitat (Matsuo *et al*. 2016). The differences in dry matter accumulation per plant and first pod insertion height were non-significant for all the varieties.

Among the physiological traits studied, SPAD at 45 DAS has shown a highly significant correlation ($p < 0.01$ %) with yield, while NDVI at 45 DAS, SPAD at 60 Days after sowing (DAS) and RWC have shown a positive correlation ($p < 0.05$ %) with the seed yield (Table 2). In the present study, the high correlation coefficient between SPAD (chlorophyll content) and seed yield at the reproductive stages, like flowering to pod-filling period, indicates that chlorophyll-based analysis could be used to estimate the soybean yield (Hou *et al*. 2019). The NDVI showing greenness index was positively correlated with the yield at 45 DAS, showing that soybean varieties with a higher value for this spectral variable during the reproductive stages contribute to the yield (Santana *et al*. 2022). Similarly, the positive association of RWC with the seed yield with a correlation coefficient of (0.768) indicates the capacity of the variety to maintain more water in leaf tissues, which can help the plant to yield under water stress conditions. Canopy temperature depression has shown a negative association with yield.

**Table 1. Response of soybean varieties in the summer season in terms of growth attributes (Pooled means).**

| Varieties | No. of days to 50% flowering | | No. of days to maturity | | Plant height (cm) | No. of branches /plant | No. of internodes/ plant | No. of clusters/ plant | Avg. pod insertion height from ground (cm) | Dry matter/plant (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Summer | Kharif | Summer | Kharif | | | | | | 30 DAS | 45 DAS | 60 DAS |
| MACS 1520 | 42 | 44 | 98 | 100 | 48.2 | 2.33 | 9 | 12 | 5.1 | 2.3 | 10.01 | 13.93 |
| MACS 1460 | 35 | 36 | 89 | 90 | 48.73 | 3.00 | 10 | 13 | 5.5 | 2.41 | 9.78 | 13.72 |
| MACS 1188 | 43 | 44 | 104 | 108 | 65.50 | 3.33 | 10 | 12 | 5.9 | 2.03 | 9.31 | 12.32 |
| KDS 726 | 43 | 45 | 105 | 110 | 61.63 | 2.50 | 10 | 12 | 5.6 | 2.65 | 9.12 | 12.15 |
| MAUS 612 | 38 | 40 | 97 | 98 | 50.7 | 3.50 | 12 | 15 | 5.7 | 2.5 | 9.65 | 13.24 |
| AMS MB 5-18 | 40 | 42 | 98 | 100 | 53.40 | 2.67 | 11 | 11 | 5.1 | 2.78 | 9.87 | 12.79 |
| KDS 753 | 42 | 44 | 101 | 105 | 54.87 | 2.50 | 10 | 11 | 5.4 | 2.46 | 10.11 | 13.07 |
| SEm (+/-) | - | - | - | - | 2.00 | 0.22 | 0.54 | 0.53 | 0.43 | 0.12 | 0.67 | 1.32 |
| CD at 0.05% | - | - | - | - | 5.76 | 0.63 | 1.55 | 1.53 | NS | NS | NS | NS |

*DAS indicates Days after sowing.

**Table 2. Correlation matrix (Pearson) between physiological parameters.**

| Traits | Yield (kg/ha) | NDVI at 30 DAS | NDVI at 45 DAS | NDVI at 60 DAS | SPAD at 30 DAS | SPAD at 45 DAS | SPAD at 60 DAS | RWC | CTD |
|---|---|---|---|---|---|---|---|---|---|
| Yield (kg/ha) | 1.0000 | | | | | | | | |
| NDVI at 30 DAS | -0.8821 | 1.0000 | | | | | | | |
| NDVI at 45 DAS | 0.8067* | -0.5978 | 1.0000 | | | | | | |
| NDVI at 60 DAS | -0.4361 | -0.0125 | -0.4615 | 1.0000 | | | | | |
| SPAD at 30 DAS | 0.7165 | -0.8290 | 0.4233 | -0.0250 | 1.0000 | | | | |
| SPAD at 45 DAS | 0.8873 ** | -0.6629 | 0.6758 | -0.6137 | 0.5301 | 1.0000 | | | |
| SPAD at 60 DAS | 0.8016 ** | -0.4877 | 0.8514 | -0.7732 | 0.3336 | 0.8440 | 1.0000 | | |
| RWC | 0.7680 ** | -0.5456 | 0.9137 | -0.4381 | 0.4850 | 0.6288 | 0.6922 | 1.0000 | |
| CTD | -0.0349 | -0.0445 | -0.4648 | 0.0704 | 0.4038 | 0.0574 | -0.3706 | -0.1637 | 1.0000 |

*DAS indicates Days after sowing. **Indicate $p < 0.05$ and $p < 0.01$, respectively.

The results of the data on yield and its attributes are presented in Table 3, showing that the number of pods and seed yield were significantly higher in variety MAUS 612 (50 no's and 1863 kg/ha) over the rest of the varieties under study and was followed by MACS 1460 (48 no's and 1764 kg/ha). Significant differences in yield of these two varieties over the remaining were owing to the increased number of branches, internodes, clusters and pods per plant. The per cent yield reduction over the average varietal yield during the Kharif season revealed that MAUS 612 (39.90%), MACS 1520 (40.44%), and MACS 1460 (41.20%) experienced less reduction compared to the other varieties. This indicates their yield stability under altered environmental conditions. However, less yield compared to regular kharif season might be due to the reduced photoperiod, low moisture in the soil, high day temperature, more flower drops, less flower and pod set, and reduction in the number of days of flowering and maturity resulting in early senescence and maturity. These results corroborate the findings of Borowska and Prusinski (2021). The highest seed index was observed in MACS 1460 (12.50 g), followed by MAUS 612 (12.47 g) and MACS 1520 (11.88) and the lowest was in KDS 726 (9.75 g). The grain production efficiency and sustainable yield index of MACS 1460 (19.57 kg/day/ha and 0.80) and MAUS 612 (19.17 kg/day/ha and 0.86) were higher than the rest of the varieties. These results conform with the findings of Ranjan (2016), who reported the prominence of YSI and GPE for higher and sustainable yields. Economic analysis of the study revealed that MAUS 612 and MACS 1460 were most remunerative in terms of gross returns, net returns and B: C ratio compared to the rest of the varieties under study.

**Table 3. Response of soybean varieties to yield, traits and economic analysis (Pooled means).**

| Varieties | No. of pods/ plant | Seed index (g) | Seed yield (kg/ha) | Grain production efficiency (kg/day/ha) | Average kharif yield (kg/ha) | Yield reduction over average yield in kharif season (%) | Sustainability yield index (SYI) | Cost of cultivation (Rs. /ha) | Gross returns (Rs. /ha) | Net returns (Rs. /ha) | B: C ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MACS 1520 | 39.0 | 11.88 | 1489 | 15.19 | 2500 | 40.44 | 0.65 | 37,321 | 66,990 | 29,669 | 1.79 |
| MACS 1460 | 48.0 | 12.50 | 1764 | 19.57 | 3000 | 41.20 | 0.80 | 37,321 | 79,380 | 42,059 | 2.13 |
| MACS 1188 | 38.0 | 10.15 | 1468 | 14.13 | 3000 | 51.07 | 0.64 | 37,321 | 66,075 | 28,754 | 1.77 |
| KDS 726 | 33.0 | 9.75 | 1219 | 12.19 | 2700 | 54.85 | 0.51 | 37,321 | 54,855 | 17,534 | 1.47 |
| MAUS 612 | 50.0 | 12.47 | 1863 | 19.17 | 3100 | 39.90 | 0.86 | 37,321 | 83,842 | 46,521 | 2.25 |
| AMS MB 5-18 | 38.0 | 11.07 | 1505 | 15.59 | 2600 | 42.12 | 0.66 | 37,321 | 67,725 | 30,404 | 1.82 |
| KDS 753 | 30.0 | 10.26 | 1105 | 11.41 | 3000 | 63.17 | 0.45 | 37,321 | 49,747 | 12,426 | 1.33 |
| SEm (+/-) | 3.68 | 0.29 | 49.48 | 0.50 | | | | | 2226 | 2204 | 0.06 |
| CD at 0.05% | 10.60 | 0.83 | 142.02 | 1.43 | | | | | 6405 | 6342 | 0.17 |

The results revealed that the germination percentage of the seed produced was significantly high in MAUS 612 (77%), followed by MACS 1460 (73%) over the other varieties (Table 4). The seedling vigour index I and II, field emergence (%), seedling emergence index (%), seedling establishment and electrical conductivity were also promising in MAUS 612 and MACS 1460 over the rest of the varieties. It might be due to the varietal genetic character (Basu and Groot 2023), low incidence of pests and disease, and absence of unseasonal rains during the maturity period that favoured a healthy atmosphere for quality seed production. Hence, soybean seeds produced during the summer season meet the quality trait criterion required for contingent seed production for the ensuing Kharif season.

**Table 4. Seed quality trait evaluation of seeds obtained in the summer-cultivated soybean (Pooled means).**

| Varieties | Germination (%) | Seedling vigour index I (%cm) | Seedling vigour index II (%mg) | Field emergence (%) | Seedling emergence index | Mean emergence time (days) | Seedling establishment | Germination rate index (% per day) | Electrical conductivity ($\mu Scm^{-1} g^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| MACS 1520 | 57 | 701 | 7450 | 50.17 | 14.06 | 5.66 | 50.17 | 8.20 | 368 |
| MACS 1460 | 73 | 968 | 12283 | 63.50 | 17.42 | 5.81 | 63.33 | 10.46 | 438 |
| MACS 1188 | 53 | 652 | 7953 | 47.17 | 12.94 | 5.55 | 47.00 | 7.65 | 371 |
| KDS 726 | 59 | 782 | 8684 | 52.00 | 14.36 | 5.67 | 52.00 | 8.51 | 333 |
| MAUS 612 | 77 | 1039 | 14574 | 67.67 | 18.14 | 5.84 | 67.67 | 11.18 | 384 |
| AMS MB 5-18 | 59 | 689 | 7914 | 51.33 | 14.64 | 5.71 | 51.33 | 8.42 | 418 |
| KDS 753 | 63 | 760 | 9188 | 49.83 | 13.42 | 5.59 | 49.83 | 8.12 | 363 |
| SEm (+/-) | 2.27 | 47 | 626 | 2.21 | 0.56 | 0.05 | 2.21 | 2.20 | 13.64 |
| CD at 0.05% | 6.53 | 134 | 1802 | 6.35 | 1.61 | NS | 6.35 | NS | 39.23 |

The present study highlights the performance of different soybean varieties under summer cultivation conditions, with slightly reduced flowering and maturity periods due to elevated temperatures and extended daylight hours, consistent with soybean's sensitivity to photoperiod and temperature. The varieties, MAUS 612 and MACS 1460 demonstrated superior performance across multiple traits. MAUS 612 exhibited the highest seed yield, while MACS 1460 followed closely, with lower yield reduction compared to their average Kharif season yields, indicating greater yield stability under summer conditions. Physiological traits showed strong positive correlations with seed yield, suggesting their potential use in yield prediction and varietal selection for cultivation in the diverse climate. Both the varieties exhibited better seed qualities including germination, seedling vigour, and emergence indices, making them highly suitable for contingent seed production. Overall, the MAUS 612 and MACS 1460 emerge as the most promising varieties for summer soybean cultivation due to their adaptability, yield potential, physiological resilience, and seed quality, thus serving as reliable options for bridging seed demand gaps when Kharif production is inadequate.

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