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Research Article

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Comparative Performance of Soybean Varieties Under Environmental Conditions of Tandojam, Pakistan

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ABSTRACT

The experiment carried out during 2021–22, aimed to compare the performance of different soybean varieties under the environmental conditions of Tandojam. The treatments included T1 = Ajmeri, T2 = Rawal, and T3 = NARC-1. The soybean Rawal ranked first with a 64.00 cm plant height, 4.60 m2 leaf area index, 0.29 g seed weight, 7610 kg ha-1 biological yield, 3666 kg ha-1 seed yield, and 48.17% harvest index. Ajmeri variety significantly and ranked 2nd with 58.49 cm plant height, 4.21 m2 leaf area index, 0.23 g seed weight, 7129 kg ha-1 biological yield, 3268 kg ha-1 seed yield, and 46.18% harvest index. The soybean variety NARC-1 ranked least in performance with 56.31 cm plant height, 3.79 m2 leaf area index, 0.17 g seed weight, 7000 kg ha-1 biological yield, 3233 kg ha-1 seed yield, and a 45.84% harvest index. From the presented study, it was concluded that of the soybean varieties evaluated in this study, the variety Rawal (48.17 kg ha-1) showed better overall performance and maximum yield as compared to Ajmeri (46.18 kg ha-1) and NARC-1 (45.84 kg ha-1). However, the newly developed variety Rawal excelled in yield traits and demonstrated promising performance, indicating its potential as a future variety.

Keywords: Soybean, temperature treatments, heat stress, crop management.

INTRODUCTION

Soybean (*Glycine max* L.) is a crucial oilseed crop grown worldwide. It is rich in protein and essential vitamins, which are vital for our daily diet. Additionally, it serves as an important cash crop for the industry and is used in biofuels (1). Soybeans also obtain some more compounds, including minerals, which are useful for health and decrease the risk of many ailments (2). The most extensively produced leguminous crop worldwide is soybean. It flourishes in tropical, subtropical, and temperate climates and provides rich protein and edible oil for human diets and animal feeding. Seeds of soybeans obtain more than 36% protein, 30% carbohydrates, and an appreciable quantity of dietary fiber, vitamins, and minerals. Soybeans are an essential crop that sustains about 20% of oil production (3). The country's average soybean yield per unit area remains significantly below its potential due to various factors. To tackle this issue, it's essential to implement strategies that can boost the productivity of soybean varieties and secure higher yield stability under diverse environmental conditions, especially in the face of climate change (4). Plant breeders and agronomists need to work on developing varieties and environment-specific production technologies to ensure growth and yield stability in soybeans. This will enable the successful cultivation of high-quality soybean varieties with promising characteristics across different environmental conditions (5). Due to the limited genetic variability among current soybean genotypes,

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a new era of crop improvement has emerged. Mutation induction is now a well-established tool in plant breeding, capable of enhancing existing germplasm and improving specific traits in cultivars (6, 32). Soybean is a short-day species that requires high temperatures, particularly during the flowering stage (7). The critical period of soybean growth is particularly sensitive to low temperatures. During this time, air temperatures between 17 and 18 °C are considered the biological minimum, while the optimal range is between 22 and 25 °C (8). Temperature, along with photoperiod, is a crucial factor influencing the development and growth of soybeans. However, it can also restrict the cultivation range of the crop (9). Elevated air temperatures and reduced rainfall enhance plant transpiration. Cultivating drought-resistant soybean cultivars, coupled with adjusting the sowing date as a no-input agrotechnical measure, offers a means to mitigate the adverse effects of weather on yields (10). One crucial aspect of soybean cultivation is the appropriate timing of seed sowing, as it profoundly influences growth, development, and ultimately yields (11). The environment in which soybeans are cultivated significantly affects their growth, development, and yield potential. Optimal conditions are crucial throughout the crop's growth stages to achieve high yields. Research has looked into the fact that to grow effectively, flower, and produce grain, the soybean cultivar has its own optimal temperature and light conditions (12). Again, in agronomy, varietal studies are the most useful methods of measuring yield stability and predicting future yield potentialities and behaviors of different varieties and management practices in different environments (13). Agronomists use multi-environment trials to evaluate different productions and efficiency options such as levels of nitrogen, densities, organic resources, cropping systems, dates of planting, and methods of sowing. According to these trials, advice is given to farmers on the best treatments suitable for their environment and cohesive between different studies (14, 34). The specific combining ability of genotypes, including soybean genotypes, also indicates that soybean genotypes differ not only among sites in yield and yield components but also in specific combining ability and agronomic traits (15, 16). Evaluating new elite soybean varieties and advanced lines is a vital process contributing to the improvement and advancement of soybean production. Consequently, this study was undertaken to compare the performance of soybean varieties under the environmental conditions of Tandojam (17, 33).

MATERIAL AND METHODS

Location, Climate, and Soil Conditions of the Study Site

Tando Jam, located at coordinates 25.4299° N and 68.5426° E, lies in the southern expanse of Sindh, a mere 20 kilometers from Hyderabad. This locale grapples with annual precipitation that falls short of sustaining crop growth independently, necessitating irrigation due to insufficient levels compared to potential evapotranspiration. The majority of rainfall occurs during the summer monsoon season, due to intermittent westerly waves that pass through the southern regions of the nation. Typically, the annual rainfall hovers between 145 and 155 mm. The proximity to the Arabian Sea tempers the climate in this research area, rendering it marginally cooler and more humid. The soil composition in this vicinity is typified by a clay loam texture, featuring a modest organic matter content ranging from 0.54% to 0.58%, coupled with elevated levels of exchangeable potassium at 165 mg kg1. However, nitrogen content registers on the lower end, ranging from 70 to 30 percent, alongside phosphorus levels spanning from 3.00 to 3.51 mg kg^{-1}.

The field experiment was carried out at the Student's Farm, Department of Agronomy, SAU, Tando Jam, to evaluate the performance of soybeans under the environmental conditions of Pakistan. The study utilized a complete RCBD with a net plot size of 5 m x 4 m (20 m^2). The recommended land preparation methods for soybean plantations were followed. The study concentrated on the local varieties Ajmeri, Rawal, and NARC-1 and was replicated three times for accuracy.

Culture Practices

A suitable seedbed was established through two dry plowings, followed by land leveling. The prescribed amount of farmyard manure was applied according to the treatments during sowing. The agronomic characteristics of the plants were monitored by the climatic conditions, with five plants selected from each plot assessed every five days during the initial 10 days after the formation of the crop.

T_1 = Ajmeri

T_2 = Rawal

T_3 = NARC-1

At the maturity stage, 15 plants were selected from each experimental unit for the measurement of their plant height (in centimeters), leaf area index, seed weight (in grams), biological yield (in kilograms per hectare), seed yield (in kilograms per hectare), and harvest index (as a percentage), with all measurements recorded.

Statistical Analysis

The collected data underwent statistical analysis using the computer software Statistix-8.1 (Statistix, 2006). The LSD test was employed to compare treatment superiority, as deemed necessary.

RESULTS

Plant Height (cm)

The varietal impact or response of plants to management factors is primarily evident in plant height. The results concerning the average plant height of three soybean varieties are outlined in Table 4.1, with the analysis of variance detailed in Appendix 1. The variance analysis revealed that the plant height variation among different varieties was statistically significant (P<0.05). Plant height was relatively greater (64.00 cm) for the newly developed soybean variety Rawal compared to the other tested varieties, followed by variety Ajmeri with a plant height of 58.49 cm, while the lowest plant height (56.31 cm) was observed in variety NARC-1. The LSD test indicated that the differences in plant height among soybean varieties were statistically significant (P<0.05).

Leaf Area Index (m^2)

The findings regarding the average leaf area index of three soybean varieties are outlined in Table 4.2, with the analysis of variance detailed in Appendix 2. The analysis of variance revealed that the variation in leaf area index among different varieties was statistically significant (P<0.05). The leaf area index was relatively higher (4.60 m2) for the newly developed soybean variety Rawal compared to the other tested varieties, followed by variety Ajmeri with a leaf area index of 4.21 m2, while the lowest leaf area index (3.79 m2) was observed in variety NARC-1. The LSD test indicated that the differences in leaf area index among soybean varieties were statistically significant (P<0.05).

Seed Weight (g)

The results concerning the average seed weight of three soybean varieties are presented in Table 4.3, with the analysis of variance detailed in Appendix 3. The analysis of variance revealed that the variation in seed weight among different varieties was statistically significant (P<0.05). Seed weight was relatively higher (0.29 g) for the newly developed soybean variety Rawal compared to the other tested varieties, followed by variety Ajmeri with a seed weight of 0.23 g, while the lowest seed weight (0.17 g) was observed in variety NARC-1. The LSD test indicated that the differences in seed weight among soybean varieties were statistically significant (P<0.05).

Biological Yield (kg ha^{-1})

Biological yield (kg/ha) encompasses the total crop biomass, including leaves, straw, awns, and grain. Variations in crop varieties may lead to differences in biological yield, with varieties having a higher biological yield potentially showing a lower harvest index. The results regarding the average biological yield of three soybean varieties are presented in Table 4.4, with the analysis of variance provided in Appendix 4. The analysis of variance revealed that the variation in biological yield among different varieties was statistically significant (P<0.05). The biological yield was relatively higher (7610 kg/ha) for the newly developed soybean variety Rawal compared to the other tested varieties, followed by variety Ajmeri with a biological yield of 7129 kg/ha, while the lowest biological yield (7000 kg/ha) was observed in variety NARC-1. The LSD test indicated that the differences in biological yield among soybean varieties were statistically significant (P<0.05).

Seed Yield (kg ha^{-1})

Seed yield (kg/ha) is a dependent trait influenced by various factors. Alongside varietal effects on seed yield (kg/ha), soil nutrient status can also impact this trait. The results regarding the average seed yield of three soybean varieties are outlined in Table 4.5, with the analysis of variance detailed in Appendix 5. The analysis of variance revealed that the variation in seed yield among different varieties was statistically significant (P<0.05). Seed yield was relatively higher (3666 kg/ha) for the newly developed soybean variety Rawal compared to the other tested varieties, followed by variety Ajmeri with a seed yield of 3268 kg/ha, while the lowest seed yield (3233 kg/ha) was observed in variety NARC-1. The LSD test indicated that the differences in seed yield among soybean varieties were statistically significant (P<0.05).

Harvest Index (%)

The findings concerning the average harvest index of three soybean varieties are outlined in Table 4.6, with the analysis of variance detailed in Appendix 6. The analysis of variance revealed that the variation in harvest index among different varieties was statistically significant (P<0.05). The harvest index was relatively higher (48.17%) for the newly developed soybean variety Rawal compared to the other tested varieties, followed by variety Ajmeri with a harvest index of 46.18%, while the lowest harvest index (45.84%) was observed in variety NARC-1. The

LSD test indicated that the differences in harvest index among soybean varieties were statistically significant ($P<0.05$).

Influence of environmental conditions on the growth, productivity, and quality of soybean crop

Varieties	Plant height (cm)	Leaf area index (m^2)	Seed weight (g)	Biological yield (kg ha^{-1})	Seed yield (kg ha^{-1})	Harvest index (%)
V_1 = Ajmeri	58.49 B	4.21 B	0.23 B	7129 B	3268 B	46.18 B
V_2 = Rawal	64.00 A	4.60 A	0.29 A	7610 A	3666 A	48.17 A
V_3 = NARC-1	56.31 C	3.79 C	0.17 C	7000 C	3233 C	45.84 C
S.E.±	0.0280	0.0319	2.7223	3.8538	0.0247	0.0260
LSD 0.05	0.0778	0.0886	7.5573	10.700	0.0686	0.0723

DISCUSSION

Soybean (*Glycine max* (L.) holds significant importance as an oilseed crop cultivated worldwide. It boasts a high protein content and is rich in essential vitamins crucial for daily nutrition. Additionally, it serves as a valuable cash crop for industries and is utilized in biofuel production (18, 35). Varietal studies are integral to agronomy as they aid in assessing yield stability and forecasting the performance of different genotypes and agronomic treatments in diverse environmental conditions (19,36). The current investigation reveals that among the soybean varieties assessed, Rawal exhibited the highest performance across multiple parameters: 64.00 cm plant height, 4.60 m^2 leaf area index, 0.29 g seed weight, 7610 $kgha^{-1}$ biological yield, 3666 $kgha^{-1}$ seed yield, and a 48.17% harvest index. Following closely, Ajmeri secured the second position with 58.49 cm plant height, 4.21 m2 leaf area index, 0.23 g seed weight, 7129 $kgha^{-1}$ biological yield, 3268 $kgha^{-1}$ seed yield, and a 46.18% harvest index. In contrast, NARC-1 displayed the lowest performance, with 56.31 cm plant height, 3.79 m^2 leaf area index, 0.17 g seed weight, 7000 $kgha^{-1}$ biological yield, 3233 $kgha^{-1}$ seed yield, and a 45.84% harvest index. Overall, Rawal demonstrated superior performance and yielded the highest output (48.17 $kgha^{-1}$) compared to Ajmeri (46.18 $kgha^{-1}$) and NARC-1 (45.84 $kgha^{-1}$). Notably, Rawal, the newly developed variety, exhibited exceptional yield traits and promising performance, suggesting its potential as a forward-looking variety. These findings are consistent with the findings of several other researchers (20, 42) Studies have indicated that soybean yield is influenced by numerous genes and is impacted by interactions between genotype and environment. Varietal stability plays a crucial role in determining how cultivars respond across diverse environments. Stability analysis seeks to assess a genotype's performance compared to others in varying environmental conditions (21, 41). Soybean producers may look for stable varieties within the range of environments of production. However, there may still be genotypes better suited to a particular environment rather than the other for their performance to be exceptional. Such an absence of varietal stability is an issue for breeding programs especially those targeting the development of varieties for multiple environments in the range of countries such as soybean breeding projects under the IITA. Hence, evaluation of the stability coefficient of a genotype in different production ecologies is important for determining their release for recommendation. Pleiotropic genes that cause cultivar characteristics need certain environmental conditions to manifest their maximum genotypic capabilities; consequently, there may be differences in the degree of expression from one environment to another (22). When different genotypes give different yields under the various test environments, they are said to exhibit genotype by environment interaction G×E. G×E reduces the extent of the relationship of individual phenotypic and genotypic values bringing about selection which does poorly when enacted across other varying environments. In MET is essential to correctly understand G×E to identify places that can distinguish the tested genotypes and to provide information about the most appropriate and informative environments. Similarly, Timilsina et al. (2023) and Nasir et al. (2023) (23, 24) reported that brix = ‘yield’ had a positive cause-and-effect relationship where an increase in soybean yield was directly proportional to the increase in the number of pods per plant. However, they did not observe any significant differences in seeds per pod or seed size. Gong et al. (2022) (25) conducted a research trial using 86 genotypes in Pakistan to examine the heritability and relationships between various yield parameters of selected genotypes. They concluded that enhanced grain yield was directly influenced by different yield contributors. Moreover, soybean, being a short-day species, has specific temperature requirements, especially during the flowering stage. This stage is crucial and particularly sensitive to low temperatures, with air temperatures ranging between 17 and 18 °C considered the biological minimum, while the optimal range falls between 22 and 25 °C (26,37). Temperature, alongside photoperiod, stands as one of the primary factors influencing the growth and developmental processes of soybeans. However, it can also impose constraints on the crop's cultivation range (27,38). Elevated air temperatures and reduced rainfall intensify plant transpiration. Cultivating drought-resistant soybean cultivars, coupled with adjusting the sowing date as a no-input agrotechnical measure, enables mitigation of the adverse effects of weather conditions on yields (28,40). An essential aspect of soybean cultivation is the timing of seed sowing, as it profoundly influences growth, development, and ultimately yields (29,39). Identifying local varieties suitable for cultivation across diverse agroecological conditions has been acknowledged as a significant challenge. Approved varieties were initially imported to Pakistan from the United States of America in the early 1960s, with commercial farming starting in 1970. Despite these efforts, soybean cultivation has shown inconsistency nationwide, and achieving sustainable high production remains elusive (30). Variability was notable among different soybean cultivars concerning metrics such as the number of pods per plant, time to reach 50% flowering, hundred-seed weight, and seed yield (31). Different soybean varieties displayed sensitivity to shifts in climatic conditions, contingent upon the cultivation area. Therefore, examining the interaction between various cultivars and their environments is essential for identifying varieties that consistently perform well in diverse conditions. The absence of high-yielding, pest-resistant, and climate change-adapted soybean cultivars poses a significant obstacle to introducing and establishing this crop in new regions.

CONCLUSIONS

From the presented study, it was concluded that of the soybean varieties evaluated in this study, the variety Rawal (48.17 kg ha^{-1}) showed better overall performance and maximum yield as compared to Ajmeri (46.18 kg ha^{-1}) and NARC-1 (45.84 kg ha^{-1}). However, the newly developed variety Rawal surpassed expectations. In terms of yield traits, it exhibited promising performance and holds potential as a variety for the future.

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