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# Revealing the Yield and Quality Responses of Soybean Advanced Lines under Semi-Arid Conditions

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## Abstract

**Background:** Soybean as human diet is a rich source of protein and oil. It also plays a vital role in livestock and poultry industries. Objective of this work is to exploit the local soybean germplasm for semi-arid conditions.

**Methods:** The experiment was conducted in Randomized Complete Block Design with three replications. Plant × plant and row × row distance was maintained as 4 inch and 1ft respectively. At maturity data for plant height, days to 50% flowering, no. of branches, no. of pods, grains per pod and grain yield per hectare were recorded. Furthermore, oil percentage, protein percentage, omega-3, omega-6, omega-9, palmitic acid and stearic acids were also measured.

**Results:** All genotypes showed highly significant difference from each other for selected traits. Grain yield per hectare was significant in genotypes such as CN-5, FS-10, E-402 and SH-1274 as compared to Faisal soybean (check). Protein and oil percentage were significantly more in CN-5, HS-17 and FS-10. Branches per plant significantly correlated with the yield but protein and oil percentage negatively correlated with each other. PCA indicated that only four out of 13 PCAs exhibited more than 1 Eigen value and showed 76.53 % variation. All traits for yield and quality were presented in PCA1, PCA2 and PCA3. Biplot indicated that genotype CN-5, SH-1274 and HB-17 falls in the positive portion that perform good.

**Conclusion:** Soybean genotypes CN-5 and FS-10 showed the more yield with high protein and oil percentage as compared to check variety and could be used in semi-arid environments.

## Introduction

Soybean (*Glycine max* L. Merr.), as a human diet is a vital resource of proteins, fats and minerals. Soybean is important feed for animals as it is rich in nutrients [1]. The nutritional and economic value of soybean has immensely raised its cultivation and use as economical agriculture crop. In oilseeds, it is vital because it contributes more than 60 percent in the oil extraction. The meal after oil extraction is a very rich source of proteins and soybean meal is highest among all others i.e. 70%. There are 40% to 42% proteins present in the soybean, while 18% to 20% oil contents are also present. The soybean oil has a good composition of saturated and unsaturated fatty acids in it i.e., 15% and 85% respectively. Saturated fatty acids in soybean include 6 % stearic acid and 9%palmitic acid. Unsaturated fatty acids include 20% omega-9, 52% omega-6, 7% omega-3 and 6% others are also present. The mineral content of soybean oil is also very diverse, it includes calcium, fiber, vitamin B-6, vitamin E, niacin and iron. It also includes phenols and flavonoids that enhance the antioxidant capabilities of this oil. More than 80% of global soybean is produced in United States, Brazil and Argentina [2].

In Pakistan soybean is considered a protein rich crop which is good for human consumption. In past twenty years, the animal feed industry has recognized the importance of soybean, specifically poultry, livestock and fisheries industry are now heavily depending on the soybean and soybean meal. The regional production of soybean is insufficient for fulfilling the demands of soybean, so the imports of soybean are growing rapidly. The first import of soybean was started in 2014-15 for oil extraction and meal production. At present, Pakistan's soybean import has raised to 2225.08 thousand tons which approximately costs nearly 123.06 billion rupees. Similarly, the soybean oil import has increased 150.91 thousand tons costs Rs.14.83 billion in 2018-19 [3] while it was negligible in 2018-19. But soybean import was negligible in 2020-21 due to covid-19 [4].

The soybean improvement is very pertinent to raise the agricultural development as well as enhancing the reliance on local productions. The improvement can be done in two perspectives, one is agronomic and other is genetic. In genetic improvement, yield improvement is very important as it is dependent on many factors [5]. Some factors pose direct impact on yield while others have indirect impact. Some components are associated with each other, and their association have degrees of impact on yield positively or negatively. The research on yield contributing factors in soybean is immense and have reported different results. The factors include number of branches in plant, number of pods, number of seeds per pod and 100 seed weight that affect the yield of soybean [6]. Researchers reported that number of pods and number of branches have important role in more yield production [7].

In Pakistan, soybean is considered as non-conventional oilseed crop despite it was introduced during 1970s along with sunflower. The main reason behind this is the lack of information regarding identification of soybean cultivars suitable for variable agro-ecological zones of country. Pakistan is predominantly a semi-arid and arid country with about 80% of its area falling in these categories [8]. Hence, it is important to develop such plant varieties which can survive and suitable for such environmental conditions. For the proper understanding of yield performance of any crop under specific set of environmental conditions, it is essential to study the contribution of various yield contributing traits towards final seed yield. It will not only help in selecting suitable variety for an agro-ecological zone but also provide guideline for breeder to develop improved varieties of a specific crop.

Current research is always looking for the components for yield improvement [9]. According to analysis of variances, correlation, and Principal component analysis (PCA) studies it was found that genotypic correlations was divided into direct and indirect effects. It was evident that these effects varied. In addition to this, statistical analysis also provided insights about the traits having visible impacts on the yield of soybean [10]. Our research objective is to reveal the high yield and good quality soybean lines with compared to check/standard variety in semi-arid environment.

## Methods

The experiment was conducted at the farm area of Oilseeds Research Institute, Ayub Agricultural Research Institute, Faisalabad. Name of fifteen lines are shown in Table 1.

| Sr. No | Lines | Sr. No | Lines | Sr. No | Lines |
|---|---|---|---|---|---|
| 1 | SS-129 | 6 | E-1097 | 11 | MCH-5 |
| 2 | HB-17 | 7 | HS-17 | 12 | E-402 |
| 3 | S-39-40 | 8 | Ajmeri | 13 | R-315 |
| 4 | TN-81-77 | 9 | FS-10 | 14 | TN-81-27-32 |
| 5 | CN-5 | 10 | Faisal Soybean (Check) | 15 | SH-1274 |

**Table 1:** List of soybean genotypes used in this study.

Land was prepared with 2-3 ploughings followed by planking. Seeds of fifteen lines were flat sown with drill in Randomized Complete Block Design (RCBD) with three replications in Kharif season 2021.Pre-emergence spray (pendimethalin 1000ml/120L) was applied after sowing in good *wattar* condition. Distance between P × P and R × R were 4 inch and 1ft maintained respectively. In the fertilizers, DAP 1 bag per acre and SOP I bag per acre at the time of sowing but Urea 1 bag

per acre with 1 and 2 irrigations in splits. Irrigation 4-5 were applied considering rainfall and environment conditions shown in Figure 1 and 2.

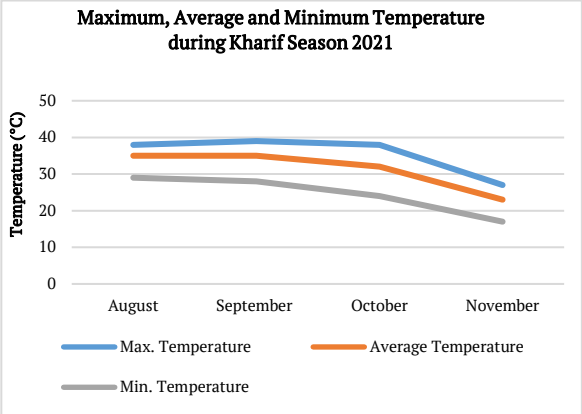


**Figure 1:** Maximum, Average and Minimum temperature during Kharif season 2021 (**Source:** Agromet Bulletin, Agricultural Meteorology Cell, University of Agriculture Faisalabad).

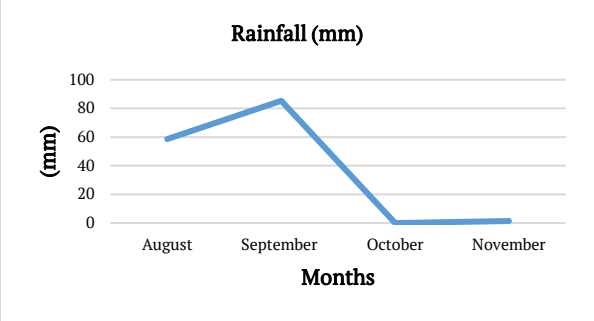


**Figure 2:** Rainfall during Kharif season 2021 (**Source:** Agromet Bulletin, Agricultural Meteorology Cell, University of Agriculture Faisalabad).

Different traits such as Plant height (cm), Days to 50% flowering, Branches per plant, Number of pods per plant, No. of grains per pods and grain yield per ha (Kg/ha) were recorded at maturity stages. Oil Percentage, Protein Percentage, omega-3 (linolenic) (%), omega-6 (linoleic) (%), omega-9 (oleic) (%), Palmitic acid (%) and Stearic acids (%) were measured with the help of Near Infra-Red spectroscopy (NIR).

### Statistical analysis

The data was analyzed with the help of an analysis of variance (ANOVA) [11]. The traits were compared with the check variety (Faisal soybean) because that is cultivated variety in semi-arid with the help of Least Significant Increase (LSI) test. The following equation was used for the LSI value.

$$LSI\ value = t\alpha(error\ d.f)\sqrt{(MSE(1/r + 1/r)}$$

Whereas,

α = 0.05

d.f. = degree of freedom

MSE = Mean SS of error

$r$ = replication

The LSI value was summed up with the mean of check/standard genotype. This value was compared to all average values of genotypes.

Pearson correlation was applied to reveal the correlation among different traits. Principle Component analysis (PCA) was applied to traits to reveal the variation contributors and desirable genotype for yield and quality.

## Results

### Analysis of variances (ANOVA)

Analysis of variance (ANOVA) indicated that plant height, days to 50% flowering, branches per plant, number of pods per plant, number of grains per pod, grain yield per ha, oil percentage, protein percentage, omega-3, omega-6, omega-9, palmitic acid and stearic acids were highly significant in the genotypes as shown in table 2.

### LSI Test (Least Significant Increase)

In our experiment, Faisal soybean was used as a check and the LSI test was used as a mean comparison test to check the difference in the traits as compared to Faisal soybean. Plant height was significant in the genotypes such as HB-17, CN-5, HS-17, FS-10 and SH-1274 as compared to the Faisal soybean plant height (59.58cm). Days to 50% flowering were significantly in the CN-5 and MCH-5 genotypes than in the Faisal soybean genotype (41.44). Branches per plant were significant in genotypes such as CN-5, MCH-5, E-402 and SH-1274 as compared to the branches per plant of Faisal soybean (3.6). The number of pods per plant was significant in genotypes such as SS-129, HB-17, CN-5, HS-17, FS-10, MCH-5, E-402 and SH-1274 as compared to the number of pods per plant of Faisal soybean (123.85). The number of grains per pod was significant in genotypes such as HB-17, S-39-40, CN-5, E-1097, HS-17, MCH-5, E-402 and SH-1274 as compared to the of number of grains per pod in Faisal soybean (2.35). Gain yield per hectare was significant in genotypes such as CN-5, FS-10, E-402 and SH-1274 as compared to the grain yield per hectare in Faisal soybean (2400.38Kg/ha). Oil percentage was significantly higher in genotypes such as SS-129, CN-5, HS-17 and FS-10 than in Faisal soybean (20.95%). Protein percentage was significant in genotypes such as HB-17, S-39-40, TN-81-77, CN-5, E-1097, HS-17, Ajmeri, FS-10, MCH-5, E-402, R-315, TN-81-27-32 and SH-1274 as compared to the protein percentage in Faisal soybean (37.90%). In comparison to the Omega-3 in Faisal soybean (6.39%), genotypes such as HB-17, S-39-40, TN-81-77, CN-5, E-1097, HS-17, Ajmeri, E-402, TN-81-27-32, and SH-1274 performed better. Omega-6 was significant in genotypes such as SS-129, HS-17 and MCH-5 compared to the Omega-6 in Faisal soybean (59.23%). Omega-9

| S.O.V | D.f | PH | Days to 50% flowering | BP | NPP | NGP | GYH | OP | PP | Omega-3 | Omega-6 | Omega-9 | PA | SA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blocks | 2 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Genotypes | 14 | 100.88** | 33.34** | 40.24** | 86.52** | 33.88** | 56.63** | 57.70** | 22.72** | 43.89** | 25.23** | 51.39** | 4.38** | 9.93** |
| Error | 28 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Total | 44 | - | - | - | - | - | - | - | - | - | - | - | - | - |

**Table 2:** F-value of soybean traits recorded at maturity.

**S.O.V:** Sources of various, **D.F:** Degree of freedom, **PH:** Plant Height, **BP:** Branches per plant, **NPP:** Number of pods per plant, **NGP:** Number of grains per pod, **GYH:** Grain Yield per hectare, **OP:** Oil Percentage, **PP:** Protein percentage, **PA:** Palmitic acid, **SA:** Stearic acid, **: Highly Significant

| Genotypes | PH (cm) | Days to 50% flowering | BP | NPP | NGP | GYPH (kg/ha) | OP (%) | PP (%) | Omega-3 (%) | Omega-6 (%) | Omega-9 (%) | PA (%) | SA (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SS-129 | 37.2 | 35 | 2.36 | 124.33* | 2.3 | 1256.34 | 21.57* | 37.87 | 6.04 | 59.49* | 14.86 | 11.57* | 4.25 |
| HB-17 | 84.33* | 41.33 | 3.33 | 161.4* | 2.43* | 1678.00 | 20.67 | 41.9* | 6.78* | 56.04 | 16.29* | 10.57 | 3.49* |
| S-39-40 | 52.53 | 39 | 1.86 | 110.23 | 2.70* | 1192.59 | 18.61 | 40.68* | 7.38* | 57.73 | 16.93* | 10.87 | 3.82* |
| TN-81-77 | 37.4 | 33 | 2.76 | 95.4 | 2.22 | 1471.00 | 20.73 | 40.64* | 6.63* | 55.26 | 20.59* | 11.32 | 4.15* |
| CN-5 | 82.33* | 55* | 4.5* | 195.7* | 2.44* | 3777.64* | 21.6* | 38.77* | 6.89* | 58.13 | 16.29* | 11.12 | 3.88* |
| E-1097 | 47.4 | 37 | 2.4 | 105.46 | 2.44* | 1229.8 | 19.61 | 42.11* | 7.55* | 56.62 | 20.55* | 11.02 | 3.88* |
| HS-17 | 85.66* | 39.66 | 2.66 | 139* | 2.39* | 1111.81 | 21.73* | 39.47* | 6.99* | 59.61* | 19.10* | 10.82 | 3.89* |
| Ajmeri | 22.4 | 36.66 | 2.5 | 81.7 | 2.25 | 1274.71 | 19.61 | 40.82* | 7.46* | 57.86 | 16.97* | 11.93* | 4.06* |
| FS-10 | 62.66* | 39.66 | 2.3 | 126.93* | 2.05 | 2633.85* | 21.37* | 41.17* | 8.28* | 55.17 | 17.70* | 11.19 | 4.01* |
| Faisal soybean | 54.13 | 39.66 | 3.2 | 114.78 | 2.15 | 2050.98 | 20.55 | 37.04 | 6.03 | 58.65 | 14.02 | 10.64 | 3.13 |
| MCH-5 | 44.26 | 44.66* | 4.16* | 155.5* | 2.46* | 581.77 | 20.48 | 39.21* | 5.08 | 59.59* | 13.40 | 11.88* | 4.30* |
| E-402 | 41.2 | 38 | 4.43* | 134.45* | 2.36* | 2829.37* | 20.84 | 39.86* | 7.75* | 55.40 | 21.20 | 13.05 | 3.69* |
| R-315 | 44.26 | 35.33 | 2.96 | 121.46 | 2.34 | 1669.96 | 20.25 | 41.21* | 5.88 | 58.97 | 16.05* | 11.6* | 4.11* |
| TN-81-27-32 | 48 | 39.33 | 2.7 | 115.1 | 2.16 | 2274.78 | 20.50 | 39.67* | 6.41* | 58.7 | 15.72* | 11.81* | 4.14* |
| SH-1274 | 71.06* | 40 | 4.7* | 149.85* | 2.49* | 3335.44* | 19.38 | 41.35* | 8.46* | 58.18 | 13.61 | 12.02* | 4.16* |

**Table 3:** LSI test to Compared genotypes with the Faisal Soybean.

**LSI value of Faisal soybean for PH:** 59.58,**Days to 50% flowering:** 41.44,**BP:**3.6, **NPP:**123.85, **NGP:**2.35, **GYH:**2400.38, **OP:**20.95, **PP:** 37.90, **Omega-3:** 6.39, **Omega-6**: 59.23, **Omega-9:** 15, PA:11.52,**SA:**3.33,*:Significant

| | PH (cm) | Days to 50% flowering (DF) | BP | NPP | NGP | GYPH (kg/ha) | OP (%) | PP (%) | Omega-3 (%) | Omega-6 (%) | Omega-9 (%) | PA (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DF | 0.59* | - | - | - | - | - | - | - | - | - | - | - |
| BP | 0.30 | 0.55* | - | - | - | - | - | - | - | - | - | - |
| NPP | 0.74* | 0.83* | 0.70* | - | - | - | - | - | - | - | - | - |
| NGP | 0.25 | 0.27 | 0.20 | 0.33 | - | - | - | - | - | - | - | - |
| GYPH (kg/ha) | 0.39 | 0.48 | 0.57* | 0.47 | -0.16 | - | - | - | - | - | - | - |
| OP (%) | 0.32 | 0.26 | 0.14 | 0.42 | -0.48 | 0.19 | - | - | - | - | - | - |
| PP (%) | 0.05 | -0.25 | -0.14 | -0.16 | 0.23 | -0.08 | -0.47* | - | - | - | - | - |
| Omega-3 (%) | 0.21 | -0.05 | 0.007 | -0.07 | 0.05 | 0.46 | -0.24 | 0.52* | - | - | - | - |
| Omega-6 (%) | 0.03 | 0.18 | 0.03 | 0.15 | 0.20 | -0.25 | 0.04 | -0.52* | -0.56* | - | - | - |
| Omega-9 (%) | -0.11 | -0.31 | -0.24 | -0.31 | -0.05 | -0.07 | 0.09 | 0.37 | 0.40 | -0.64* | - | - |
| PA (%) | -0.50 | -0.15 | 0.45 | -0.06 | -0.06 | 0.20 | -0.06 | 0.01 | 0.13 | -0.06 | 0.09 | - |
| SA (%) | -0.33 | -0.14 | -0.04 | -0.07 | 0.03 | -0.21 | -0.002 | 0.20 | -0.07 | 0.22 | -0.08 | 0.42 |

**Table 4:** Pearson Correlations among the traits, * $p < 0.05$.

| | PCA1 | PCA2 | PCA3 | PCA4 | PCA5 | PCA6 | PCA7 | PCA8 | PCA9 | PCA10 | PCA11 | PCA12 | PCA13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Eigenvalue | 3.7423 | 2.6341 | 1.8361 | 1.8044 | 0.9984 | 0.7529 | 0.4638 | 0.3409 | 0.1611 | 0.1386 | 0.0897 | 0.0342 | 0.0035 |
| Variability (%) | 28.7872 | 20.2622 | 14.1242 | 13.8798 | 7.6799 | 5.7913 | 3.5679 | 2.6224 | 1.2391 | 1.0663 | 0.6898 | 0.2633 | 0.0266 |
| Cumulative % | 28.7872 | 49.0493 | 63.1735 | 77.0533 | 84.7332 | 90.5245 | 94.0924 | 96.7148 | 97.9539 | 99.0203 | 99.7101 | 99.9734 | 100.0000 |

**Table 5:** Contribution of PCAs to Eigen value, variation (%) and cumulative (%)

| Traits | PCA1 | PCA2 | PCA3 | PCA4 | PCA5 | PCA6 | PCA7 |
|---|---|---|---|---|---|---|---|
| PH | 0.3754 | 0.1998 | -0.3330 | 0.1143 | 0.1973 | -0.1801 | 0.0751 |
| DF | 0.4528 | 0.0442 | -0.0063 | 0.0847 | 0.0530 | 0.0205 | 0.0215 |
| BP | 0.3642 | 0.1208 | 0.4002 | -0.0041 | -0.1173 | 0.2734 | -0.2788 |
| NPP | 0.4843 | 0.0731 | 0.0418 | 0.0764 | 0.2467 | 0.0727 | -0.1406 |
| NGP | 0.1077 | 0.0594 | 0.0364 | 0.6462 | 0.0806 | 0.3913 | 0.3012 |
| GYPH | 0.2965 | 0.3233 | 0.1757 | -0.2354 | -0.3140 | -0.2882 | 0.1410 |
| OP | 0.2204 | -0.0906 | -0.1103 | -0.5375 | 0.4750 | 0.0485 | 0.0837 |
| PP | -0.2033 | 0.3922 | 0.0221 | 0.3248 | 0.2656 | -0.2131 | -0.4712 |
| Omega-3 | -0.0635 | 0.5270 | 0.0453 | 0.0349 | -0.1023 | -0.3353 | 0.4936 |
| Omega-6 | 0.1513 | -0.4950 | 0.0607 | 0.2021 | -0.0192 | -0.1732 | 0.4334 |
| Omega-9 | -0.2304 | 0.3501 | -0.1023 | -0.1874 | 0.3396 | 0.5067 | 0.3266 |
| PA | -0.0644 | 0.0602 | 0.6849 | -0.1341 | -0.0329 | 0.1939 | 0.1155 |
| SA | -0.1151 | -0.1385 | 0.4439 | 0.1063 | 0.5960 | -0.4080 | 0.0723 |

**Table 6:** PCA values of rotation component matrix for seven variables of fifteen genotypes of soybean.

| Observation | PCA1 | PCA2 | PCA3 | PCA4 | PCA5 |
|---|---|---|---|---|---|
| SS-129 | -0.5248 | -2.8397 | 0.3894 | -0.9567 | 0.6249 |
| HB-17 | 1.3582 | 1.3714 | -2.0450 | 0.8695 | 0.2755 |
| S-39-40 | -1.4274 | 0.2454 | -1.1260 | 2.9792 | -0.7499 |
| TN-81-77 | -2.5707 | 0.5661 | -0.0847 | -1.2461 | 0.8417 |
| CN-5 | 5.0423 | 0.7960 | 0.0771 | -0.3226 | 0.4473 |
| E-1097 | -2.2010 | 1.4040 | -0.8821 | 1.0909 | 0.3405 |
| HS-17 | 0.8583 | -0.5663 | -1.8093 | -0.0932 | 1.5691 |
| Ajmeri | -2.7331 | -0.2925 | 0.9665 | 0.0973 | -0.7131 |
| FS-10 | -0.5075 | 1.9958 | -0.7573 | -1.8973 | 0.6049 |
| Faisal soybean | 1.0744 | -1.7387 | -1.9244 | -1.4926 | -2.7967 |
| MCH-5 | 1.3770 | -2.8396 | 1.6125 | 1.2116 | 0.8079 |
| E-402 | -0.0914 | 2.3848 | 2.1563 | -1.5925 | -0.4957 |
| R-315 | -0.8967 | -1.1431 | 0.5827 | 0.5303 | 0.2828 |
| TN-81-27-32 | -0.3789 | -1.0675 | 0.7043 | -0.8542 | -0.1687 |
| SH-1274 | 1.6215 | 1.7238 | 2.1401 | 1.6766 | -0.8704 |

**Table 7:** PCA score of soybean genotypes

was significant in genotypes such as HB-17, S-39-40, TN-81-77, CN-5, E-1097, HS-17, Ajmeri, FS-10, R-315 and TN-81-27-32 as compared to the Omega-9 in Faisal soybean (15%). Palmitic acid was significant in genotypes such as SS-129, Ajmeri, MCH-5, R-315, TN-81-27-32 and SH-1274 as compared to the Palmitic acid in Faisal soybean (11.52%). Stearic acid was significant in genotypes such asHB-17, S-39-40, TN-81-77, CN-5, E-1097, HS-17, Ajmeri, FS-10, MCH-5, E-402, R-315, TN-81-27-32 and SH-1274 as compared to the stearic acid in Faisal soybean (3.33%) as shown in table 3. In genotypes such as CN-5, FS-10, E-402 and SH-1274 showed more gain yield per hectare than the Faisal soybean. Protein and oil percentages were higher in CN-5, HS-17, and FS-10 genotypes than in Faisal soybean. The genotypes such as CN5 and FS-10 showed the more yield as well as high protein and oil percentage as compared to Faisal soybean.

### Correlation (Pearson) analysis among the traits

Correlation among the traits indicated that plant height was significantly and positively correlated with days to 50% flowering and number of pods per plant. Increase in plant height also enhanced in days to 50% flowering and number of pods per plant. Days to 50% flowering significantly and positively correlated with branches per plant and number of pods per plant. Branches per plant were significantly and positively correlated with the number of pods per plant and grain yield per hectare. Oil percentage was significantly and negatively correlated with the protein percentage. Protein percentage was significantly positively and negatively correlated with omega-3 and omega-6 respectively. Omega-3 was significantly and negatively correlated with omega-6. But omega-6 was significantly and negatively correlated with omega-9 as shown in table 4.

### Principle component analysis (PCA)

The PCA indicated that only four out of 13 PCAs exhibited more than 1 Eigen value and showed 76.53 % variation. More variation proportions of 28.78%, 20.26%,14.12% and 13.37%were in the PCA1, PCA2, PCA3 and PCA4, respectively. Other from PCA5 to PCA13 showed the least variation as shown in the table 5. Table 6 revealed that the PCA1, which accounted for the highest variability (28.78%) was mostly related to traits such as plant height, days to 50% flowering, branches per plant, number of pods per plant, number of grains per pod, grain yield per hectare, oil percentage and omega-6. In PCA2, the traits such as plant height, branches per plant, grain yield per hectare, protein percentage, omega-3 and omega-9 were more related. PCA3 is dominated by branches per plant, palmitic acid, and stearic acid. PCA4 was more related to the number of grains per plant and protein (%). All traits for yield and quality were presented in PCA1, PCA2 and PCA3. PCA1 indicated that the CN-5 at the top score of 5.04 followed by SH-1274, MCH-5, HB-17 and Faisal soybean had high values for plant height, days to 50% flowering, branches per plant, number of pods per plant, number of grains per pod, grain yield per hectare, oil percentage and omega-6. E-402, FS-10, SH-1274, E-1097 and HB-17 had high values in PCA2. E-402, SH-1274 and MCH-5 had high values in PCA 3.S-39-40, SH-1274, MCH-5 and E-1097 had high values in PCA4. Only HS-17 had a high value in PCA5 as shown in table 7.

The genotypes had more distance from the Centre, which showed more diversity. The genotypes such as CN-5, SH-1274 and HB-17 fall into the positive portion that performs well. The genotypes such as SS-129 and Ajmeri that fall into the negative section perform poorly. More diversity was observed in the CN-5, MCH-5, E-402, FS-10, E-1092 and TN-81-7.

## Discussion

Our experiment results are closely similar to the previous research work such as the plant height, days to 50% flowering, branches per plant, number of pods per plant, number of grains per pod and grain yield per ha are significant [12, 13]. The other studies do not include quality parameters such as oil percentage, protein percentage, omega-3, omega-6, omega-9, palmitic acid, and stearic acid. The number of pods and seeds [14, 15] are the most important traits for the selection of an economical yield. Honest Significance

Differences (HSD) as a mean comparison test but the LSI was used to compare the result with the check/standard i.e. Faisal soybean [13]. It indicated that genotypes such as CN-5, HS-17 and FS-10 have more yield as compared to Faisal soybean.

Plant height is not significantly correlated with days to 50% flowering and number of pods per plant [16], but our results show a significantly and positive correlation [17, 18]. Days to 50% flowering were found to be non-significantly correlated with branches per plant, pods per plant, and grain yield per hectare [16], but significantly and positively correlated with branches per plant and number of pods per plant in our results. It was found that the number of branches per plant is significant and positively correlated with the number of pods per plant [18], which is similar to our findings, but the number of pods per plant is significantly correlated with plant height and the number of branches per plant, which are not in our findings. Protein percentage and oil percentage is negatively and significantly correlated. Quality parameters such as unsaturated fatty acids (omega-3, omega-6 and mega-9) and saturated fatty acids correlations are not discussed in previous research.

It was reported that 73.44% variation in PCA1 to PCA5 but 76.53% variation in PCA1 to PCA4 and has more than 1 Eigen value [19]. The PCA1, which accounted for the highest variability (28.78%) was mostly related with traits such as plant height, days to 50% flowering, branches per plant, number of pods per plant, number of grains per pod and grain yield per hectare.

The genotypes such as CN5 and FS-10 showed the more yield as well as high protein and oil percentage as compared to Faisal soybean. Branches per plant significantly correlated with the yield but protein and oil percentage negatively correlated with each other. PCA indicated that only four out of 13 PCAs exhibited more than 1 Eigen value and showed 76.53 % variation. All traits for yield and quality were presented in PCA1, PCA2 and PCA3. PCA1 indicated that the CN-5 at the top score 5.04 followed by SH-1274, MCH-5, HB-17 and Faisal soybean had high value for plant height, days to 50% flowering, branches per plant, number of pods per plant, number of grains per pod, grain yield per hectare, oil percentage and omega-6. E-402, FS-10, SH-1274, E-1097 and HB-17 had high value in PCA2. E-402, SH-1274 and MCH-5 had high value in PCA 3.S-39-40, SH-1274, MCH-5 and E-1097 had high value in PCA4. Only HS-17 had high value in PCA5. Biplot indicated that genotype such as CN-5, SH-1274 and HB-17 fall into the positive portion that perform good.

## Competing Interest

The authors declare that there is no conflict of interest.

## Author Contributions

All authors contributed equally to this study.

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