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Research Article

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Screening the Soybean Varietal Lines for Selecting High-Yielding and Better Agronomic Traits Producing lines

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Abstract

Soybean (*Glycine max*), an economically significant legume originating from East Asia, serves as a valuable source of protein and oil globally. In Pakistan, soybean is considered a non-conventional oilseed crop, with successful cultivation possible during both the spring and summer seasons. The careful selection of appropriate varieties is a primary concern for soybean growers in the country. The objectives of the study were to select high yielding varieties in semi-arid climate. A total of forty-six newly developed varietal lines, which have not yet been released, were evaluated alongside four released varieties (Ajmeri, Faisal, Jack, and Rawal) that are already being cultivated in various regions of the country. The field experiments were carried out at the experimental area of the Nuclear Institute of Agriculture (NIA) in Tando Jam during the spring and summer seasons of 2018. Important agronomic traits were recorded for each varietal. The results indicate significant variations among the varietal lines for all evaluated characteristics. Based on grain production, NIBGE32 line produced 30% higher yield as compared to top performing control variety Faisal. Other newly developed varietal lines, namely NIBGE 8, NIBGE 9, NIBGE 18, NIBGE 32, NIBGE 41, and NIBGE 45, also demonstrated promising high-yield potential. These varieties displayed comparatively superior growth and yield outcomes. Germination percentage significantly vary in the spring and summer season (Mann-Whitney U =7925, P<0.01); whereas days to maturity, plant height, leaf area, lowest pod height, 100-grain weight, biological yield, and seed weight per plant, were not significantly different in two seasons. This suggests a NIBGE32 has potential to be cultivated in both seasons. This research endeavors to offer valuable insights and recommendations to farmers and policymakers, aiming to augment soybean production and advance agricultural sustainability in the region of Sindh.

Keywords: Soybean, *Glycine max*, screening, yield, semi-arid, moderate temperature.

Introduction

Soybeans have become a valuable and economical agricultural crop around the globe due to its outstanding nutritional value and health advantages in human diets and animal fodders (Gawęda *et al*., 2020; Mishra *et al*., 2022). The estimated global cultivation area of soybeans is roughly 129 million hectares (FAO, 2020). Brazil, the United States of America, Argentina, China, and India are the most prominent nations in soybean production (FAO, 2020). This crop ranks fourth in terms of cultivation, following wheat, rice, and maize (Staniak *et al*., 2023). A significant portion of Pakistan's foreign exchange reserves is allocated towards the import of soybean edible oil and oilseed-based food/ feedstocks (Asad *et al*., 2020). Photoperiodic flowering is one of the most important phenomena that affects the adaptation of soybean genotypes in an environment and production (Lin *et al*., 2021). Soybean genotypes' adaptability is based on how sensitive they are to day length. This is because day length directly affects their flowering and growth trends, especially when it comes to short or long photoperiods (Osnato *et al*., 2022). The Photoperiod sensitivity may vary in soybean varieties which means they can grow well in a wide range of latitudes (Rani *et al*., 2023). For short-duration crops to grow well in places with high temperatures and long days, they must be less sensitive to light (Rani *et al*., 2023). During many stages of its growth cycle, soybean is sensitive to the length of the days; this includes the pre-flowering period, and the post-flowering stage (Krisnawati & Muchlish Adie, 2021) In Pakistan, commercial soybean cultivation began in the early 1970s, sparking a sizable effort in varietal assessment. Pakistan still makes a minor contribution to the world's soybean production and struggles to meet domestic demand for edible oil and various soybean derivatives. As a result, the nation is dependent on imports to supply its demand for soybean products and edible oil. There are several reasons behind Pakistan's low soybean production. The lack of high-yielding cultivars suitable for various agro-climatic zones and growing seasons is one of them (Asad *et al*., 2020). Furthermore, soybean germplasm is not very diverse, especially in terms of photo-insensitive germplasm (Asad *et al*., 2020). Competition from established crops in various regions of the country has an additional negative impact on restricted soybean production. However, many geographical regions with agro-climatic conditions are favourable for the cultivation of soybeans in Pakistan (Khurshid, 2017). The major goal of breeders is to cultivate genotypes that demonstrate consistent and high-yield performance throughout a diverse range of climatic conditions. The genotypes of soybeans observed in both cultivated and wild species often display adaptations to specific climatic conditions, hence influencing their reproductive efficacy and capacity to attain substantial yields. (Rani *et al*., 2023) Given that these factors have a significant impact on the growth and productivity of plants. The careful selection of an appropriate genotype in accordance with specific environmental conditions is of utmost importance. The assessment of genotypes for specific environments relies on the use of yield rankings. We investigated the adaptability of a recently developed varietal line in the semi-arid region. It is crucial to evaluate the suitability of a newly developed varietal line in this specific region to ensure optimal yield and productivity. The new varieties may produce enhanced yield, optimize resource utilization and adopt to climate change to ensure food security.

Materials and methods

Site of the study: The research work was carried out for two seasons in 2018 and the Nuclear Institute of Agriculture (NIA) Tandojam, Sindh Pakistan. The experiment was conducted over two consecutive seasons (Spring and Summer of 2018).

Plant Material: The collection of fifty soybean germplasm and varietal lines was sourced from the Agricultural Research Service-United States Department of Agriculture (ARS-USDA), Plant Genetic Resources Program, National Agricultural Research Centre (PGRP-NARC) Islamabad, and the National Institute of Biotechnology and Genetic Engineering (NIBGE), Faisalabad. As control varieties, the study employed four widely cultivated, high-yielding soybean varieties (Ajmeri, Faisal, Jack, and Rawal,). The purpose of using these control varieties was to compare the performance of the varietal lines against well-established and successful varieties.

Experimental Design: The experiment was conducted in a randomized complete block design (RCBD) with three replications to avoid bias. The plant-to-plant and row-to-row space was maintained at 10 cm and 30cm, respectively. The rows were five meters long with a one-meter-wide path in between two replications.

Weather conditions and Physiochemical analysis of soil: The soil sample was obtained from two distinct depths (30 cm and 60 cm) and mixed. The physical and chemical characteristics of the soil were analyzed (Table 1). The soil texture was identified utilizing the Bouyoucos hydrometer method (Bouyoucos 1962), with the addition of 10% sodium hexametaphosphate for particle dispersion. Hydrometer measurements of soil suspension density were taken at a calibrated 20°C, ensuring accurate correction within the 15-25°C range. Consequently, the determined soil texture class was clay loam. A pH meter was used to determine the pH of the soil. The organic matter content of the soil was 0.69%. Organic matter helps to improve soil fertility and overall soil health. The soil parameters Kjeldahl Nitrogen (%) 0.073, AB-DTPA extractable- Potassium K (mg kg-1) 187, and AB-DTPA extractable- Phosphorus P (mg kg-1) 4.34 were also investigated (Table 1).

Table. 1 Physio-chemical characteristics of soil used in Soybean trials in Sindh.

S. No.	Parameters		Tandojam
1	EC (dS/m^{-1})		2.1
2	PH		8.2
3	Texture		Clay loam
5	Texture	Sand	21.7%
		Silt	42.2%
		Clay	36.1%
6	Organic matter		0.69%
7	Nitrogen		0.073%
8	Potassium (mg kg^{-1})		187
9	Phosphorous (mg kg^{-1})		4.34

The weather data of the study area (temperature, humidity, and precipitation) was obtained from the Pakistan Metrological Department (PMD, 2019). In the spring season from sowing to harvesting the average minimum temperature was 18°C and the average maximum temperature was 36°C (Figure 1

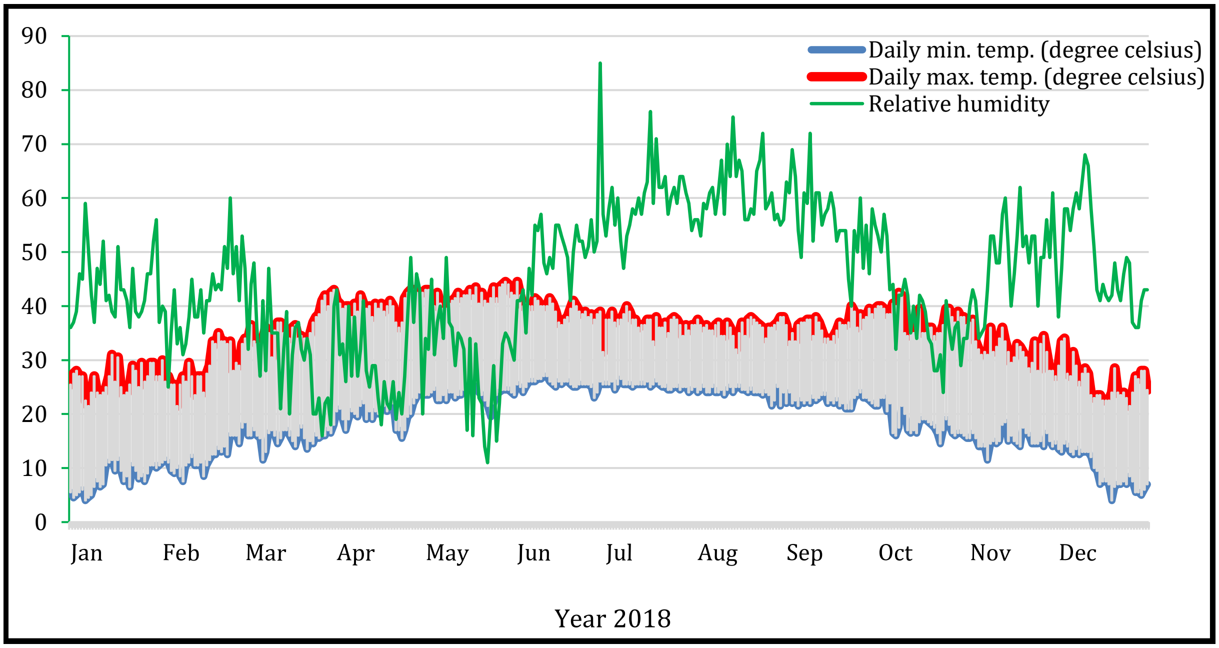

Fig. 1. Daily weather recorded in the spring and summer seasons of the year 2018 at Tandojam (PMD, 2019

Furthermore, soybean germplasm is not very diverse, especially in terms of photo-insensitive germplasm (Asad *et al*., 2020). Competition from established crops in various regions of the country has an additional negative impact on restricted soybean production. However, many geographical regions with agro-climatic conditions are favourable for the cultivation of soybeans in Pakistan (Khurshid, 2017).

The major goal of breeders is to cultivate genotypes that demonstrate consistent and high-yield performance throughout a diverse range of climatic conditions. The genotypes of soybeans observed in both cultivated and wild species often display adaptations to specific climatic conditions, hence influencing their reproductive efficacy and capacity to attain substantial yields. (Rani *et al*., 2023) (Table 2).

Table 2 The weather conditions during the crop season in summer and spring of 2018.

Season	Month	Temperature ^{0}C			Humidity (%)	Precipitation (mm)	Cropping stage
		Minimum	Maximum	Mean			
Spring	February	11.2	28.7	19.95	41.4	00	Sowing
	March	15.8	36	25.9	31.6	2	Vegetative Stage
	April	20.1	40.2	30.15	30.3	0	Reproductive Stage
	May	23	41	32	29	0	Harvesting Stage
	June	25	39.3	32.15	50.6	7.2	Harvesting Stage
Summer	July	25.2	37	31.1	59.4	05	Sowing
	August	24	36.1	30.05	61	3	Vegetative Stage
	September	22.4	36.6	29.5	15.9	0	Reproductive Stage
	October	18.1	37.6	27.85	38.4	0	Harvesting Stage
	November	15.1	31.91	23.50	48.5	0	Harvesting Stage

Agricultural practices: Prior to seed sowing, seed sterilization was done by exposing them to chlorine gas for 48 hours. The land was pre-irrigated with canal water during both growing seasons to maintain optimal moisture for seed germination. Before sowing the seeds, the soil was tilled three times using conventional plowing methods to promote healthy germination, plant growth, weed control, and to incorporate manure and fertilizer. Twenty seeds of each variety were sown at a depth of 2.5 to 5 cm which is considered suitable for better results (Madanzi *et al*., 2010). The crop was irrigated four times as per requirement. The initial watering was done after fifteen days of sowing. The weeding was performed by hand hoeing and hand weeding when necessary. To prevent fungal growth on soybean crops, fungicides are applied. In this study, no insect disease indicators were observed, so insecticides were not used. The recommended dose of NPK fertilizer was applied at the time of sowing and flowering stage. The soybean crop was harvested in late May from spring trial and mid-October from summer trial.

Agro-morphological observations: Fourteen morphological and Yield characteristics were examined over the course of two consecutive seasons in 2018, and data were gathered for further analysis **(Table 3).**

Table 3. Measurements and Observations for screening the better agronomic characteristic of soybean varietal lines.

Parameters	Abbreviation	Procedure
Germination	G%	Germination (%) = total seed germination/total seeds × 100
Days to flowering	DF	In the early stages of flowering, from the time of the seedling Stage of development characterized by the presence of 50% of plants with an open flower in the first reproductive stage (Lu *et al*., 2017). The number of days to flowering were counted.
Days to maturity	DM	The number of days after emergence and the date of full maturity which is defined as the presence of 50% of useful area with 95% of mature pods.
Leaf area (cm^2)	LA	The leaf area was measured using the Leaf Area Index Meter (AM350 portable leaf area meter).
Plant height at maturity	PHM	The height of the plant was measured by using measuring tape from the soil surface to the apex of the raceme of the main stem, and the average was calculated from the height of three randomly sampled plants in each row.
Plant population at harvesting	PPH	The population of plants was noted when the harvest was done.
Number of pods per plant	NPP	At maturity, the number of pods per plant was assessed by counting the number of pods present in three randomly selected plants.
100 grains weight	100GW	The 100-grain weight was recorded by manually separating 100 grains and weighing with an electric balance.
Seed weight per plant	SWP	Total seed weight produced by a single plant at the time of harvest.
Total grain yield	TGY	Total grain yield was evaluated at final maturity (harvest time). Grain weight was determined by hand threshing pods.
Plant habit	PH	Habit - erect or prostrate
Seed color,	SC	Seed colour - yellow, brown, green, black
Flower color	FC	Flower colour - Pink, white
Harvest Index	HI	The HI was calculated according to the following formula: Harvest index (%) = Grain yield / Biological yield × 100

Statistical analysis: Analysis of variance (ANOVA) with Duncan's multiple range test (DMRT) at $p<0.05$ was used to analyse the data in SPSS version 20 (IBM Corp. 2011). Summer and spring effects on vegetative and reproductive traits were compared using the Mann-Whitney Test. The "Dist" function in the R programming language was employed to compute the distance matrix of the genotypes, utilizing phenotypic data, and employing the "Euclidean" technique (Micheaux *et al*., 2013). The hierarchical cluster analysis was conducted with the "hclust" program. The dissimilarity matrix generated by the "dist" function was utilized to create clusters using the "complete" clustering approach. The "fviz_dend" function from the fact extra R package and ggplot2 was employed to improve the visualization of the dendrogram.

RESULT AND DISCUSSION

Germination and morphological traits: The germination percentage (G%) of the soybean varietal lines varied and ranged between 52 and 79.7 in both in spring and summer seasons **(**Table. 4).

Table 4. Germination percentage (G%), Days to flowering (DF) and Days to maturity (DM) of soybean lines tested during the spring and summer seasons of the year 2018.

Varieties	Germination Percentage		Days to flowering		Days to maturity	
	Spring	Summer	Spring	Summer	Spring	Summer
Ajmeri C	58.3 ± 1.99 $^{s-z}$	68.0 ± 1.99 $^{e-l}$	37.0 ± 0.46 $^{k-m}$	37.0 ± 0.46 $^{k-m}$	92.0 ± 0.43 ^{fg}	92.0 ± 0.43 ^{fg}
Faisal C	68.0 ± 1.99 $^{e-l}$	71.3 ± 1.99 $^{c-g}$	41.6 ± 0.46 ^{ab}	41.6 ± 0.46 ^{ab}	93.7 ± 0.43 ^{cd}	93.7 ± 0.43 ^{cd}
Jack C	65.0 ± 1.99 $^{h-q}$	68.0 ± 1.99 $^{e-l}$	35.6 ± 0.46 $^{m-o}$	35.6 ± 0.46 $^{m-o}$	92.7 ± 0.43 $^{d-f}$	92.7 ± 0.43 $^{d-f}$
Rawal C	67.7 ± 1.99 $^{f-m}$	67.3 ± 1.99 $^{f-n}$	37.0 ± 0.46 ^{kl}	37.0 ± 0.46 kl	91.3 ± 0.43 ^{gh}	91.3 ± 0.43 ^{gh}
NIBGE 1	61.7 ± 1.99 $^{o-w}$	64.0 ± 1.99 $^{j-r}$	35.6 ± 0.46 $^{m-o}$	35.6 ± 0.46 $^{m-o}$	90.3 ± 0.43 ^{hi}	90.3 ± 0.43 ^{hi}
NIBGE 2	58.0 ± 1.99 $^{s-ad}$	60.7 ± 1.99 $^{p-y}$	35.6 ± 0.46 $^{m-o}$	35.6 ± 0.46 $^{m-o}$	92.7 ± 0.43 $^{d-f}$	92.7 ± 0.43 $^{d-f}$
NIBGE 3	70.7 ± 1.99 $^{d-h}$	73.7 ± 1.99 $^{b-d}$	39.3 ± 0.46 $^{e-g}$	39.3 ± 0.46 $^{e-g}$	92.7 ± 0.43 $^{d-f}$	92.7 ± 0.43 $^{d-f}$
NIBGE 4	54.0 ± .99 $^{ac-ag}$	58.3 ± 1.99 $^{s-ad}$	38.0 ± 0.46 $^{h-k}$	38.0 ± 0.46 $^{h-k}$	91.7 ± 0.43 ^{fg}	91.7 ± 0.43 ^{fg}

NIBGE 5	69.0 ± 1.99 $^{d-j}$	72.0 ± 1.99 $^{c-g}$	38.3 ± 0.46 $^{g-j}$	38.3 ± 0.46 $^{g-j}$	93.7 ± 0.43 ^{cd}	93.7 ± 0.43 ^{cd}
NIBGE 6	62.3 ± 1.99 $^{m-u}$	68.0 ± 1.99 $^{e-l}$	38.0 ± 0.46 $^{h-k}$	38.0 ± 0.46 $^{h-k}$	93.7 ± 0.43 ^{cd}	93.7 ± 0.43 ^{cd}
NIBGE 7	54.3 ± .99 $^{ab-ag}$	56.3 ± 1.99 $^{w-af}$	41.6 ± 0.46 ^{ab}	41.6 ± 0.46 ^{ab}	93.7 ± 0.43 ^{cd}	93.7 ± 0.43 ^{cd}
NIBGE 8	56.7 ± 1.99 $^{v-af}$	60.0 ± 1.99 $^{q-aa}$	40.3 ± 0.46 $^{c-e}$	40.3 ± 0.46 $^{c-e}$	90.0 ± 0.43 ^{i}	90.0 ± 0.43 ^{i}
NIBGE 9	73.3 ± 1.99 $^{b-e}$	78.0 ± 1.99 $^{a-b}$	34.0 ± 0.46 ^{qr}	34.0 ± 0.46 ^{qr}	90.3 ± 0.43 ^{hi}	90.3 ± 0.43 ^{hi}
NIBGE 10	52.0 ± 1.99 $^{af-ag}$	55.0 ± 1.99 $^{z-ag}$	37.0 ± 0.46 ^{kl}	37.0 ± 0.46 ^{kl}	93.3 ± 0.43 $^{c-e}$	93.3 ± 0.43 $^{c-e}$
NIBGE 11	67.0 ± 1.99 $^{f-o}$	71.0 ± 1.99 $^{c-h}$	38.0 ± 0.46 $^{g-k}$	38.0 ± 0.46 $^{g-k}$	94.0 ± 0.43 ^{cd}	94.0 ± 0.43 $^{c-e}$
NIBGE 12	59.7 ± 1.99 $^{q-ab}$	64.7 ± 1.99 $^{i-q}$	39.0 ± 0.46 $^{f-h}$	39.0 ± 0.46 $^{f-h}$	92.7 ± 0.43 $^{d-f}$	92.7 ± 0.43 $^{d-f}$
NIBGE 13	69.7 ± 1.99 $^{d-i}$	72.7 ± 1.99 $^{b-f}$	37.6 ± 0.46 $^{i-k}$	37.6 ± 0.46 $^{i-k}$	94.3 ± 0.43 ^{c}	94.3 ± 0.43 ^{c}
NIBGE 14	58.3 ± 1.99 $^{s-ad}$	65.0 ± 1.99 $^{h-q}$	38.6 ± 0.46 $^{f-i}$	38.6 ± 0.46 $^{f-i}$	99.0 ± 0.43 ^{a}	99.0 ± 0.43 ^{a}
NIBGE 15	54.7 ± 1.99^{aa-ag}	67.3 ± 1.99 $^{f-n}$	38.6 ± 0.46 $^{f-i}$	38.6 ± 0.46 $^{f-i}$	89.3 ± 0.43 ^{ij}	89.3 ± 0.43 ^{ij}
NIBGE 16	72.0 ± 1.99 $^{c-g}$	79.7 ± 1.99 ^{a}	39.6 ± 0.46 $^{d-f}$	39.6 ± 0.46 $^{d-f}$	91.7 ± 0.43 ^{fg}	91.7 ± 0.43 ^{fg}
NIBGE 17	50.3 ± 1.99 $^{a-g}$	55.3 ± 1.99 $^{y-ag}$	37.3 ± 0.46 ^{jk}	37.3 ± 0.46 ^{jk}	89.7 ± 0.43 ^{i}	89.7 ± 0.43 ^{i}
NIBGE 18	58.3 ± 2.44 $^{s-ad}$	65.7 ± 1.99 $^{h-p}$	39.6 ± 0.46 $^{d-f}$	39.6 ± 0.46 $^{d-f}$	92.3 ± 0.43 $^{e-g}$	92.3 ± 0.43 $^{e-g}$
NIBGE 19	60.7 ± 3.45 $^{p-y}$	65.0 ± 1.99 $^{h-q}$	34.6 ± 0.46 $^{o-q}$	34.6 ± 0.46 $^{o-q}$	92.7 ± 0.43 $^{d-f}$	92.7 ± 0.43 $^{d-f}$
NIBGE 20	53.7 ±1.99 $^{ac-ag}$	56.0 ± 1.99 $^{x-ag}$	39.3 ± 0.46 $^{e-g}$	39.3 ± 0.46 $^{e-g}$	91.7 ± 0.43 ^{fg}	91.7 ± 0.43 ^{fg}
NIBGE 21	61.7 ± 1.99 $^{o-w}$	67.7 ± 1.99 $^{f-m}$	34.3 ± 0.46 $^{p.r}$	34.3 ± 0.46 $^{p.r}$	93.7 ± 0.43 ^{cd}	93.7 ± 0.43 ^{cd}
NIBGE 22	65.0 ± 1.99 $^{h-q}$	71.7 ± 1.99 $^{c-g}$	36.6 ± 0.46 $^{k-m}$	36.6 ± 0.46 $^{k-m}$	93.3 ± 0.43 $^{c-e}$	93.3 ± 0.43 $^{c-e}$
NIBGE 23	59.0 ± 1.99 $^{r-ac}$	68.7 ± 1.99 $^{d-k}$	42.6 ± 0.46 ^{a}	42.6 ± 0.46 ^{a}	93.3 ± 0.43 $^{c-e}$	93.3 ± 0.43 $^{c-e}$
NIBGE 24	66.7 ± 1.99 $^{g-o}$	71.7 ± 1.99 $^{c-g}$	36.6 ± 0.46 $^{k-m}$	36.6 ± 0.46 $^{k-m}$	89.3 ± 0.43 ^{ij}	89.3 ± 0.43 ^{ij}
NIBGE 25	72.7 ± 1.99 $^{b-f}$	76.7 ± 1.99 $^{a-c}$	36.6 ± 0.46 $^{k-m}$	36.6 ± 0.46 $^{k-m}$	90.0 ± 0.43 ^{i}	90.0 ± 0.43 ^{i}
NIBGE 26	64.0 ± 1.99 $^{j-r}$	67.3 ± 1.99 $^{f-n}$	34.6 ± 0.46 $^{o-r}$	34.6 ± 0.46 $^{o-r}$	92.3 ± 0.43 $^{e-g}$	92.3 ± 0.43 $^{e-g}$
NIBGE 27	53.7 ±3.45 $^{ac-ag}$	57.0 ± 1.99 $^{u-ag}$	36.6 ± 0.46 $^{m-o}$	36.6 ± 0.46 $^{m-o}$	94.7 ± 0.43 ^{c}	94.7 ± 0.43 ^{c}
NIBGE 28	67.3 ± 1.99 $^{f-n}$	69.7 ± 1.99 $^{d-i}$	41.3 ± 0.46 ^{bc}	41.3 ± 0.46 ^{bc}	99.7 ± 0.43 ^{a}	99.7 ± 0.43 ^{a}
NIBGE 29	65.7 ± 1.99 $^{h-p}$	69.7 ± 1.99 $^{d-i}$	39.3 ± 0.46 $^{n-p}$	39.3 ± 0.46 $^{n-p}$	89.3 ± 0.43 ^{ij}	89.3 ± 0.43 ^{ij}
NIBGE 30	57.3 ± 1.99 $^{u-af}$	60.3 ± 1.99 $^{p-z}$	38.6 ± 0.46 $^{f-i}$	38.6 ± 0.46 $^{f-i}$	90.3 ± 0.43 ^{hi}	90.3 ± 0.43 ^{hi}
NIBGE 31	52.3 ±1.99 $^{ae-ag}$	54.7 ± 1.99 $^{aa-ag}$	38.0 ± 0.46 $^{h-k}$	38.0 ± 0.46 $^{h-k}$	92.3 ± 0.43 $^{e-g}$	92.3 ± 0.43 $^{e-g}$
NIBGE 32	68.0 ± 1.99 $^{e-l}$	72.3 ± 1.99 $^{c-f}$	34.6 ± 0.46 $^{o-r}$	34.6 ± 0.46 $^{o-r}$	91.3 ± 0.43 ^{gh}	91.3 ± 0.43 ^{gh}
NIBGE 33	58.7 ± 1.99 $^{r-ad}$	60.3 ± 1.99 $^{p-z}$	38.6 ± 0.46 $^{f-i}$	38.6 ± 0.46 $^{f-i}$	93.3 ± 0.43 $^{c-e}$	93.3 ± 0.43 $^{c-e}$
NIBGE 34	60.0 ± 1.99 $^{q-aa}$	66.7 ± 1.99 $^{g-o}$	33.6 ± 0.46 ^{r}	33.6 ± 0.46 ^{r}	89.3 ± 0.43 ^{ij}	89.3 ± 0.43 ^{ij}
NIBGE 35	57.7 ± 1.99 $^{t-ae}$	57.7 ± 1.99 $^{t-ag}$	39.0 ± 0.46 $^{f-h}$	39.0 ± 0.46 $^{f-h}$	91.7 ± 0.43 ^{fg}	91.7 ± 0.43 ^{fg}
NIBGE 36	58.3 ± 1.99 $^{s-ad}$	59.0 ± 1.99 $^{r-ac}$	34.0 ± 0.46 ^{qr}	34.0 ± 0.46 ^{qr}	88.0 ± 0.43 ^{k}	88.0 ± 0.43 ^{k}
NIBGE 37	68.3 ± 1.99 $^{d-l}$	69.7 ± 1.99 $^{d-i}$	33.6 ± 0.46 ^{r}	33.6 ± 0.46 r	87.7 ± 0.43 ^{k}	87.7 ± 0.43 ^{k}
NIBGE 38	61.7 ± 2.44 $^{o-w}$	63.0 ± 1.99 $^{l-t}$	34.6 ± 0.46 $^{o-r}$	34.6 ± 0.46 $^{o-r}$	91.7 ± 0.43 ^{fg}	91.7 ± 0.43 ^{fg}
NIBGE 39	56.3 ± 1.99 $^{w-af}$	57.7 ± 1.99 $^{t-ae}$	36.0 ± 0.46 $^{l-n}$	36.0 ± 0.46 $^{l-n}$	89.7 ± 0.43 ^{i}	89.7 ± 0.43 ^{i}
NIBGE 40	53.7 ±1.99 $^{ac-ag}$	53.7 ± 1.99 $^{ac-ag}$	35.0 ± 0.46 $^{n-p}$	35.0 ± 0.46 $^{n-p}$	93.7 ± 0.43 ^{cd}	93.7 ± 0.43 ^{cd}
NIBGE 41	61.3 ± 1.99 $^{o-x}$	63.3 ± 1.99 $^{k-s}$	36.0 ± 0.46 $^{l-n}$	36.0 ± 0.46 $^{l-n}$	89.3 ± 0.43 ^{ij}	89.3 ± 0.43 ^{ij}
NIBGE 42	53.3 ±1.99 $^{ad-ag}$	57.7 ± 1.99 $^{t-ae}$	36.0 ± 0.46 $^{l-n}$	36.0 ± 0.46 $^{l-n}$	92.3 ± 0.43 $^{e-g}$	92.7 ± 0.43 $^{e-g}$
NIBGE 43	53.7 ±1.99 $^{ac-ag}$	56.7 ± 1.99 $^{v-af}$	40.6 ± 0.46 $^{b-d}$	40.6 ± 0.46 $^{b-d}$	92.7 ± 0.43 $^{d-f}$	92.7 ± 0.43 $^{d-f}$
NIBGE 44	59.0 ± 1.99 $^{r-ac}$	62.0 ± 1.99 $^{n-v}$	40.3 ± 0.46 $^{c-e}$	40.3 ± 0.46 $^{c-e}$	87.3 ± 0.43 ^{k}	87.3 ± 0.43 ^{k}
NIBGE 45	60.7 ± 1.99 $^{p-y}$	65.0 ± 1.99 $^{h-q}$	39.3 ± 0.46 $^{e-g}$	39.3 ± 0.46 $^{e-g}$	88.3 ± 0.43 ^{jk}	88.3 ± 0.43 ^{jk}
NIBGE 46	62.0 ± 1.99 $^{n-v}$	66.7 ± 1.99 $^{g-o}$	35.6 ± 0.46 $^{m-o}$	35.6 ± 0.46 $^{m-o}$	97.7 ± 0.43 ^{b}	97.7 ± 0.43 ^{b}

Values before the ± are the means of the sample, and values after ± are the Standard error of the mean. Means with the same letter are not significantly different a p<0.05.

The best germination percentage was recorded in NIBGE 9 in spring and in NIBGE 16 in summer season. The mean G% of Soybean varietal lines in the summer season (64.9 ± 6.8) were significantly higher than that in the spring season (Mann-Whitney U =7925, P<0.01). In both the spring and summer, there was a significant variation in the germination percentage of different varieties of soybeans. The higher percentage of soybean varietal lines that germinate in the summer can be attributed to a variety of factors. Initially, it has been suggested that summertime temperatures might promote faster and more efficient germination (Yamaguchi-Shinozaki & Shinozaki, 1994; Szczerba *et al*., 2021). Soybeans germinate best around 25 degrees Celsius and stop at 10 degrees (Sharma *et al*., 2005). Second, longer summer days might mean more sunshine for photosynthesis, which would improve the health and germination rates of seedlings. Days to flowering (DF) in varietal lines varied between 33.6 and 41.6. The DF also varied in the season. The varietal lines reached flowering stages early in summer season as compared to spring (Table 4). Notably, NIBGE 34 exhibited a higher level of performance in terms of flowering. This finding indicates that NIBGE 34 outperformed the control varieties in terms of flowering time than the control varieties Ajmeri is 41.0 days, Faisal has a duration of 41.6 days, Jack has a duration of 35 days, and Rawal has a duration of 37 days. Regarding days to maturity (DM), the varietal lines reached maturity between 87.3 (± 0.43) and 99.7 (± 0.43) days from the time of sowing, with an average of 92 days taken by 50 varietal lines to mature. NIBGE 44 exhibited the shortest days to maturity during the summer (87.3 days). The days to maturity were not significantly different in spring and summer seasons (Mann-Whitney U =11250, P=1.0) (Table 4). The varietal lines displayed an earlier flowering time and maturity during the summer season compared to the spring season. The early flowering and maturity of soybean varietal lines during the summer season is most likely attributed to the warm temperatures and extended daylight hours that are typical during this period (Kezar *et al*., 2023). Warmer temperatures promote the growth and development of plants, while extended daylight hours supply additional sunlight for the process of photosynthesis, enhancing the strength and vitality of seedlings and promoting higher rates of blooming. The findings are consistent with other studies on the identical topic (Hou *et al*., 2023; Tujuba, 2020). The soybean varieties reached maturity in 85 days in a dry environment while in wet conditions the DM extended to 97 days (Weerasekara *et al*., 2021). The Leaf area (LA) among the varietal lines of soybean varied between 6.7 ± 0.31 cm2 (NIBGE 41) and 37.2 ± 0.31 cm2 (NIBGE 1). There was no significant difference between the average leaf area (cm2) in summer and spring seasons (Mann-Whitney Test, U=11250, P=1) **(Table 5)**.

Table 5. Leaf area (LA), Plant height at maturity (PHM), and Plant population at harvesting (PPH) of soybean lines tested during the spring and summer seasons of the year 2018.

Varieties	Leaf area (cm^2)		Plant height at maturity (cm)		Plant population at harvesting	
	Spring	**Summer**	**Spring**	**Summer**	**Spring**	**Summer**
Ajmeri C	16.3 ± 2.20 $^{j-o}$	26.0 ± 2.20 $^{g-i}$	26.0 ± 0.54 $^{g-i}$	26.0 ± 0.54 $^{g-i}$	9.33± 0.41^{r-t}	9.67 ± 0.41^{q-r}
Faisal C	18.6 ± 2.20 $^{g-n}$	25.7 ± 2.20 ^{hi}	25.7 ± 0.54 ^{hi}	25.7 ± 0.54 ^{hi}	6.33± 0.41^{y-ab}	6.00 ± 0.41^{z-ab}
Jack C	14.6 ± 2.20 $^{l-p}$	18.3 ± 2.20 ^{q}	18.3 ± 0.54 ^{q}	18.3 ± 0.54 ^{q}	6.00± 0.41^{z-ab}	6.00 ± 0.41^{z-ab}
Rawal C	16.2 ± 2.20 $^{j-o}$	29.0 ± 2.20 ^{d}	29.0 ± 0.54 ^{d}	29.0 ± 0.54 ^{d}	9.67± 0.41^{q-s}	10.0 ± 0.41^{p-r}
NIBGE 1	37.2 ± 2.20 ^{a}	27.0 ± 2.20 $^{f-h}$	27.0 ± 0.54 $^{f-h}$	27.0 ± 0.54 $^{f-h}$	8.00± 0.41^{u-w}	8.00 ± 0.41^{u-w}
NIBGE 2	26.8 ± 2.20 ^{cd}	41.0 ± 2.20 ^{a}	41.0 ± 0.54 ^{a}	41.0 ± 0.54 ^{a}	10.0± 0.41^{p-r}	11.0 ± 0.41^{m-p}
NIBGE 3	35.7 ± 2.20 ^{a}	21.7 ± 2.20 $^{m-p}$	21.7 ± 0.54 $^{m-p}$	21.7 ± 0.54 $^{m-p}$	10.0± 0.41^{p-r}	11.0 ± 0.41^{m-p}
NIBGE 4	25.9 ± 2.20 $^{c-e}$	24.7 ± 2.20 $^{i-k}$	24.7 ± 0.54 $^{i-k}$	24.7 ± 0.54 $^{i-k}$	9.33± 0.41^{r-t}	10.0 ± 0.41^{p-r}
NIBGE 5	28.8 ± 2.20 $^{b-d}$	22.3 ± 2.20 $^{l-o}$	22.3 ± 0.54 $^{l-o}$	22.3 ± 0.54 $^{l-o}$	8.67± 0.41^{s-u}	8.67 ± 0.41^{s-u}
NIBGE 6	27.0 ± 2.20 ^{cd}	28.0 ± 2.20 $^{d-f}$	28.0 ± 0.54 $^{d-f}$	28.0 ± 0.54 $^{d-f}$	10.3± 0.41^{o-r}	11.0 ± 0.41^{m-p}
NIBGE 7	28.9 ± 2.20 $^{b-d}$	36.0 ± 2.20 ^{c}	36.0 ± 0.54 ^{c}	36.0 ± 0.54 ^{c}	11.0± 0.41^{m-p}	11.6 ± 0.41^{k-n}
NIBGE 8	20.9 ± 2.20 $^{d-k}$	21.3 ± 2.20 $^{n-p}$	21.3 ± 0.54 $^{n-p}$	21.3 ± 0.54 $^{n-p}$	11.3± 0.41^{l-o}	11.0 ± 0.41^{m-p}
NIBGE 9	24.5 ± 2.20 $^{d-g}$	27.3 ± 2.20 $^{e-g}$	27.3 ± 0.54 $^{e-g}$	27.3 ± 0.54 $^{e-g}$	14.6± 0.41^{e-g}	15.6 ± 0.41^{c-e}
NIBGE 10	17.2 ± 2.20 $^{i-o}$	22.7 ± 2.20 $^{l-n}$	22.7 ± 0.54 $^{l-n}$	22.7 ± 0.54 $^{l-n}$	7.67± 0.41^{u-w}	7.67 ± 0.41^{u-x}
NIBGE 11	25.7 ± 2.20 $^{c-f}$	37.0 ± 2.20 ^{b}	37.0 ± 0.54 ^{b}	37.0 ± 0.54 ^{b}	11.0± 0.41^{u-x}	12.5 ± 0.41^{i-l}
NIBGE 12	22.7 ± 2.20 $^{d-i}$	25.3 ± 2.20 ^{i}	25.3 ± 0.54 ^{i}	25.3 ± 0.54 ^{i}	13.0± 0.41^{h-j}	13.6 ± 0.41^{g-i}
NIBGE 13	16.1 ± 2.20 $^{j-o}$	37.3 ± 2.20 ^{bc}	37.3 ± 0.54 ^{bc}	37.3 ± 0.54 ^{bc}	12.0± 0.41^{j-m}	12.6 ± 0.41^{i-k}
NIBGE 14	25.3 ± 2.20 $^{d-f}$	25.0 ± 2.20 ^{ij}	25.0 ± 0.54 ^{ij}	25.0 ± 0.54 ^{ij}	8.67± 0.41^{s-u}	8.67 ± 0.41^{s-u}
NIBGE 15	23.4 ± 2.20 $^{d-h}$	27.7 ± 2.20 $^{d-f}$	27.7 ± 0.54 $^{d-f}$	27.7 ± 0.54 $^{d-f}$	14.6± 0.41^{e-g}	15.6 ± 0.41^{c-e}
NIBGE 16	33.9 ± 2.20 ^{ab}	29.0 ± 2.20 ^{d}	29.0 ± 0.54 ^{d}	29.0 ± 0.54 ^{d}	15.3± 0.41^{d-f}	17.3 ± 0.41^{ab}
NIBGE 17	8.4 ± 2.20 ^{pq}	20.7 ± 2.20 ^{p}	20.7 ± 0.54 ^{p}	20.7 ± 0.54 ^{p}	13.6± 0.41^{g-i}	14.6 ± 0.41^{e-g}
NIBGE 18	31.6 ± 2.20 $^{a-c}$	28.0 ± 2.20 $^{d-f}$	28.0 ± 0.54 $^{d-f}$	28.0 ± 0.54 $^{d-f}$	10.0± 0.41^{p-r}	10.6 ± 0.41^{n-q}
NIBGE 19	12.8 ± 2.20 $^{n-q}$	25.0 ± 2.20 ^{ij}	25.0 ± 0.54 ^{ij}	25.0 ± 0.54 ^{ij}	11.3± 0.41^{y-ab}	6.33 ± 0.41^{y-ab}
NIBGE 20	18.4 ± 2.20 $^{g-o}$	18.3 ± 2.20 ^{q}	18.3 ± 0.54 ^{q}	18.3 ± 0.54 ^{q}	11.6± 0.41^{l-o}	11.0 ± 0.41^{m-p}
NIBGE 21	17.5 ± 2.20 $^{h-o}$	17.3 ± 2.20 ^{qr}	17.3 ± 0.54 ^{qr}	17.3 ± 0.54 ^{qr}	5.33± 0.41^{k-n}	12.3 ± 0.41^{j-l}
NIBGE 22	24.0 ± 2.20 $^{d-g}$	23.7 ± 2.20 $^{j-l}$	23.7 ± 0.54 $^{j-l}$	23.7 ± 0.54 $^{j-l}$	10.0± 0.41^{ab}	5.67 ± 0.41^{aa-ab}
NIBGE 23	23.1 ± 2.20 $^{d-i}$	29.0 ± 2.20 ^{d}	29.0 ± 0.54 ^{d}	29.0 ± 0.54 ^{d}	10.0± 0.41^{p-r}	10.6 ± 0.41^{n-q}
NIBGE 24	25.0 ± 2.20 $^{d-f}$	24.7 ± 2.20 $^{i-k}$	24.7 ± 0.54 $^{i-k}$	24.7 ± 0.54 $^{i-k}$	12.0± 0.41^{p-r}	10.6 ± 0.41^{n-q}
NIBGE 25	15.6 ± 2.20 $^{j-o}$	23.7 ± 2.20 $^{j-l}$	23.7 ± 0.54 $^{j-l}$	23.7 ± 0.54 $^{j-l}$	13.0± 0.41^{j-m}	12.6 ± 0.41^{i-k}
NIBGE 26	27.2 ± 2.20 ^{cd}	23.7 ± 2.20 $^{j-l}$	23.7 ± 0.54 $^{j-l}$	23.7 ± 0.54 $^{j-l}$	7.67± 0.41^{h-j}	14.0 ± 0.41^{gh}
NIBGE 27	16.2 ± 2.20 $^{j-o}$	29.0 ± 2.20 ^{d}	29.0 ± 0.54 ^{d}	29.0 ± 0.54 ^{d}	15.6± 0.41^{u-x}	7.67 ± 0.41^{u-x}
NIBGE 28	20.6 ± 2.20 $^{d-l}$	27.7 ± 2.20 $^{d-f}$	27.7 ± 0.54 $^{d-f}$	27.7 ± 0.54 $^{d-f}$	11.6± 0.41^{c-e}	16.6 ± 0.41^{a-c}
NIBGE 29	15.7 ± 2.20 $^{j-o}$	28.7 ± 2.20 ^{de}	28.7 ± 0.54 ^{de}	28.7 ± 0.54 ^{de}	11.3± 0.41^{k-n}	12.6 ± 0.41^{i-k}
NIBGE 30	25.8 ± 2.20 $^{c-e}$	23.7 ± 2.20 $^{j-l}$	23.7 ± 0.54 $^{j-l}$	23.7 ± 0.54 $^{j-l}$	8.00± 0.41^{u-w}	8.00 ± 0.41^{u-w}
NIBGE 31	21.7 ± 2.20 $^{d-j}$	25.7 ± 2.20 ^{hi}	25.7 ± 0.54 ^{hi}	25.7 ± 0.54 ^{hi}	16.3± 0.41^{b-d}	17.6 ± 0.41^{a}
NIBGE 32	18.6 ± 2.20 $^{g-n}$	28.0 ± 2.20 $^{d-f}$	28.0 ± 0.54 $^{d-f}$	28.0 ± 0.54 $^{d-f}$	14.6± 0.41^{e-g}	16.3 ± 0.41^{b-d}
NIBGE 33	26.0 ± 2.20 $^{c-e}$	25.3 ± 2.20 ^{i}	25.3 ± 0.54 ^{i}	25.3 ± 0.54 ^{i}	6.00± 0.41^{z-ab}	6.00 ± 0.41^{z-ab}
NIBGE 34	13.5 ± 2.20 $^{m-p}$	28.3 ± 2.20 $^{d-f}$	28.3 ± 0.54 $^{d-f}$	28.3 ± 0.54 $^{d-f}$	7.33± 0.41^{v-y}	7.33 ± 0.41^{v-y}
NIBGE 35	13.5 ± 2.20 $^{m-p}$	25.3 ± 2.20 ^{I}	25.3 ± 0.54 ^{i}	25.3 ± 0.54 ^{I}	10.0± 0.41^{p-r}	10.0 ± 0.41^{p-r}

NIBGE 36	20.1 ± 2.20 $^{e-l}$	28.3 ± 2.20^{d-f}	28.3 ± 0.54 $^{d-f}$	28.3 ± 0.54 $^{d-f}$	14.3± 0.41^{e-g}	14.6 ± 0.41^{e-g}
NIBGE 37	19.5 ± 2.20 $^{f-m}$	23.3 ± 2.20 ^{kl}	23.3 ± 0.54 $^{k-l}$	23.3 ± 0.54 ^{kl}	12.6± 0.41^{i-k}	12.6 ± 0.41^{i-k}
NIBGE 38	14.5 ± 2.20 $^{l-p}$	22.3 ± 2.20 $^{l-o}$	22.3 ± 0.54 $^{l-o}$	22.3 ± 0.54 $^{l-o}$	7.00± 0.41^{x-aa}	6.67 ± 0.41^{x-aa}
NIBGE 39	14.9 ± 2.20 $^{k-o}$	20.7 ± 2.20 ^{p}	20.7 ± 0.54 ^{p}	20.7 ± 0.54 ^{p}	11.0± 0.41^{o-r}	10.3 ± 0.41^{o-r}
NIBGE 40	23.0 ± 2.20 $^{d-i}$	21.0 ± 2.20 ^{op}	21.0 ± 0.54 ^{op}	21.0 ± 0.54 ^{op}	10.6± 0.41^{o-r}	10.3 ± 0.41^{o-r}
NIBGE 41	6.7 ± 2.20 ^{q}	14.7 ± 2.20 ^{s}	14.7 ± 0.54 ^{s}	14.7 ± 0.54 ^{s}	8.00± 0.41^{u-w}	8.00 ± 0.41^{u-w}
NIBGE 42	12.3 ± 2.20 $^{o-q}$	16.7 ± 2.20 ^{r}	16.7 ± 0.54 ^{r}	16.7 ± 0.54 ^{r}	7.00± 0.41^{w-z}	7.00 ± 0.41^{w-z}
NIBGE 43	12.3 ± 2.20 $^{o-q}$	23.0 ± 2.20 ^{lm}	23.0 ± 0.54 ^{lm}	23.0 ± 0.54 ^{lm}	8.33± 0.41^{t-v}	8.33 ± 0.41^{t-v}
NIBGE 44	13.9 ± 2.20 $^{m-p}$	17.3 ± 2.20 ^{qr}	17.3 ± 0.54 ^{qr}	17.3 ± 0.54 ^{qr}	7.67± 0.41^{v-y}	7.33 ± 0.41^{v-y}
NIBGE 45	17.4 ± 2.20 $^{h-o}$	18.3 ± 2.20 ^{q}	18.3 ± 0.54 ^{q}	18.3 ± 0.54 ^{q}	8.67± 0.41^{s-u}	8.67 ± 0.41^{s-u}
NIBGE 46	15.4 ± 2.20 $^{k-o}$	16.7 ± 2.20 ^{r}	16.7 ± 0.54 ^{r}	16.7 ± 0.54 ^{r}	7.00± 0.41^{w-z}	7.00 ± 0.41^{w-z}

Values before the ± are the means of the sample, and values after ± are the Standard error of the mean. Means with the same letter are not significantly different a p<0.05.

The leaf area has been estimated using the leaf blade's length and width (de Sá *et al*., 2022). The lack of a significant difference in leaf area between summer and spring suggests that environmental factors specific to these seasons may not have a substantial impact on the overall leaf area of soybean plants in this study. However, it is critical to recognize the study's limitations, such as the unique climatic circumstances and places where the research was conducted. This result is significant because it sheds light on the variability of leaf area among soybean varietal lines, which has implications for a variety of agricultural practices. Understanding the variation in leaf area size is crucial for tasks like optimizing planting density, irrigation, and pest management (Teobaldelli *et al*., 2019).The plant height at maturity (PHM) of the varieties varied. Varietal line NIBGE 2 (41 ± 0.5 cm) had the tallest plant while NIBGE 41 had a dwarf plant with an average height of 15 ± 0.5 cm, and it was significantly different from all other varieties in spring and summer seasons **(Table 5)**. There was no significant difference between the average plant height in summer and spring seasons (Mann-Whitney Test, U=11250, P=1). Maximum PPH was recorded in the summer for the NIBGE 31 (17.6 ± 0.41), NIBGE 16 (17.3 ± 0.41), NIBGE 28 (16.6 ± 0.41), and NIBGE 32 (16.3 ± 0.41) line. The lowest PPH value was found in NIBGE 22 (5.6 ± 0.41). Similarly in spring, the highest density of plants was recorded in NIBGE 31 (16.3 ± 0.41) while the lowest density was recorded in NIBGE 22 (5.3 ± 0.41) (Table 5). Plant populations at harvest were discussed, with planting dates and densities that corresponded to local producer practices (Ali *et al*., 2013). The four types of varieties, including Rawal (23 m-2), Williams-82, SA-72-60, and PSC-60, had plant populations reported during harvest (Junior *et al*., 2015). The PHM is an important trait related to soybean adaptability and productivity, The PHM mean of 74.6 while the range 27.4 to 117.7 cm has been reported (Zhang *et al*., 2015). Regarding Plant habit (PH), all varieties have an erect habit while NIBGE 11 has prostrate habit. Erect varieties showed an increase in yield and a spreading variety showed no response (**Table 6**).

Table 6. Total grains yield (TGY), color of seed (CS), color of flower (CF) and plant habit (PH) of soybean lines tested during the spring and summer seasons of the year 2018.

Varieties	Total grains yield		Qualitative Characteristics		
	Spring	Summer	Color of Seed (CS)	Color of Flower (CF)	Plant Habit (PH)
Ajmeri C	132± 4.55^{l-p}	155± 4.55^{ij}	Yellow	Pink	Erect
Faisal C	44 ± 4.55^{aq-as}	45± 4.55^{ap-as}	Yellow	Pink	Erect
Jack C	44 ± 4.55^{ap-as}	47± 4.55^{an-as}	Yellow	White	Erect
Rawal C	109 ± 4.55^{v-x}	119± 4.55^{t-w}	Yellow	White	Erect
NIBGE 1	109 ± 4.55^{v-x}	119± 4.55^{q-v}	Yellow	Pink	Erect
NIBGE 2	76 ± 4.55^{ab-af}	77± 4.55^{ab-af}	Yellow	White	Erect
NIBGE 3	111 ± 4.55^{u-w}	117± 4.55^{s-v}	Yellow	Pink	Erect
NIBGE 4	121 ± 4.55^{p-v}	130± 4.55^{n-r}	Yellow	Pink	Erect
NIBGE 5	123 ± 4.55^{o-u}	128± 4.55^{n-s}	Yellow	Pink	Erect
NIBGE 6	75 ± 4.55^{ab-ag}	81± 4.55^{aa-ae}	Yellow	Dark pink	Erect
NIBGE 7	69 ± 4.55^{ad-ah}	72± 4.55^{ab-ah}	Yellow	Pink	Erect
NIBGE 8	183 ± 4.55^{h}	203± 4.55^{fg}	Yellow	Pink	Erect
NIBGE 9	207 ± 4.55^{fg}	242± 4.55^{c}	Yellow	White	Erect
NIBGE 10	48 ± 4.55^{am-as}	51± 4.55^{ak-as}	Yellow	White	Erect
NIBGE 11	73± 4.55^{ab-ah}	80± 4.55^{aa-af}	Yellow	Pink	Prostrate
NIBGE 12	143± 4.55^{j-m}	156± 4.55^{ij}	Yellow	Pink	Erect
NIBGE 13	144± 4.55^{j-l}	156± 4.55^{ij}	Yellow	Light pink	Erect

NIBGE 14	46± 4.55^{ao-as}	50± 4.55^{ak-as}	Yellow	Pink	Erect
NIBGE 15	44± 4.55^{aq-as}	48± 4.55^{am-as}	Yellow	Pink	Erect
NIBGE 16	198± 4.55^{g}	221± 4.55^{de}	Yellow	White	Erect
NIBGE 17	211± 4.55^{ef}	224± 4.55^{d}	Yellow	Pink	Erect
NIBGE 18	208± 4.55^{fg}	222± 4.55^{de}	Yellow	Pink	Erect
NIBGE 19	41± 4.55^{ar-as}	45± 4.55^{ap-as}	Yellow	White	Erect
NIBGE 20	50± 4.55^{ak-as}	56± 4.55^{ai-aq}	Yellow	White	Erect
NIBGE 21	119± 4.55^{q-v}	134± 4.55^{l-o}	Yellow	Pink	Erect
NIBGE 22	39± 4.55^{as}	39± 4.55^{as}	Yellow	White	Erect
NIBGE 23	69± 4.55^{ad-ah}	72± 4.55^{ab-ah}	Yellow	Pink	Erect
NIBGE 24	152± 4.55^{i-k}	161± 4.55^{i}	Yellow	Pink	Erect
NIBGE 25	97± 4.55^{x-z}	103± 4.55^{w-y}	Yellow	White	Erect
NIBGE 26	78± 4.55^{ab-af}	82± 4.55^{aa-ad}	Yellow	White	Erect
NIBGE 27	79± 4.55^{ab-af}	86± 4.55^{z-ab}	Yellow	White	Erect
NIBGE 28	70± 4.55^{ac-ah}	75± 4.55^{ab-ag}	Yellow	White	Erect
NIBGE 29	55± 4.55^{aj-aq}	56± 4.55^{ai-aq}	Yellow	White	Erect
NIBGE 30	58± 4.55^{ah-aq}	60± 4.55^{ah-am}	Yellow	White	Erect
NIBGE 31	131± 4.55^{m-q}	140± 4.55^{k-n}	Yellow	White	Erect
NIBGE 32	336± 4.55^{b}	356± 4.55^{a}	Yellow	White	Erect
NIBGE 33	53± 4.55^{ak-ar}	60± 4.55^{ah-am}	Yellow	Pink	Erect
NIBGE 34	61± 4.55^{ah-al}	67± 4.55^{af-aj}	Yellow	White	Erect
NIBGE 35	59± 4.55^{ah-ao}	63± 4.55^{ag-ak}	Yellow	White	Erect
NIBGE 36	117± 4.55^{r-v}	124± 4.55^{o-t}	Yellow	Pink	Erect
NIBGE 37	127± 4.55^{o-s}	130± 4.55^{n-r}	Yellow	Pink	Erect
NIBGE 38	44± 4.55^{ap-as}	51± 4.55^{ak-as}	Dark green	Pink	Erect
NIBGE 39	123± 4.55^{o-u}	125± 4.55^{o-t}	Yellow	Pink	Erect
NIBGE 40	68± 4.55^{ae-ai}	72± 4.55^{ab-ah}	Yellow	Pink	Erect
NIBGE 41	47± 4.55^{am-as}	49± 4.55^{al-as}	Yellow	Pink	Erect
NIBGE 42	82± 4.55^{aa-ac}	92± 4.55^{y-aa}	Yellow	Pink	Erect
NIBGE 43	102± 4.55^{w-y}	110± 4.55^{vw}	Yellow	Pink	Erect
NIBGE 44	51± 4.55^{ak-as}	59± 4.55^{ah-an}	Yellow	White	Erect
NIBGE 45	148± 4.55^{i-j}	149± 4.55^{i-k}	Black	White	Erect
NIBGE 46	54± 4.55^{ak-ar}	57± 4.55^{ah-ap}	Yellow	White	Erect

Values before the ± are the means of the sample, and values after ± are the Standard error of the mean. Means with the same letter are not significantly different a $p<0.05$.

Plant habits (erect and prostate) hold significant importance. Erect types are best for high-density planting with compact canopies, while prostrate types are best for sparse planting. In soybean, chickpea, and some bean genotypes, erect stem architecture improves harvesting and disease resistance. Forage and biomass production are better with prostrate legumes like cowpeas. Since prostrate cultivars yield less, erect cultivars are preferred in commercial agriculture, where manual harvesting is expensive. When pods touch the soil, microclimate effects reduce grain yield in prostrate cultivars (Li *et al*., 2022; Kuzbakova *et al*., 2022; Kushwah *et al*., 2020; Araméndiz-Tatis *et al*., 2023; Choi *et al*., 2021). In terms of Flower color (FC), twenty varietal lines and two control varieties, Rawal and Jack, have white flowers while the remaining varieties had pink flowers (Table 6). Whereas the soybean seeds can vary greatly in seed color (SC). The seed color of variety NIBGE 38 was green color, NIBGE 45 appeared as black color while the remaining sown varieties were found yellow color including control varieties (Table 6). The seeds of different soybean varieties exhibit a range of colors, including yellow, green, black, and various shades of brown. However, it is noteworthy that most commercially cultivated soybean cultivars possess a yellow hue. The genetic regulation governs the colors of seeds, except for green hues, which are present in the Testa, a seed coat characterized by its leathery texture (Kafer *et al*., 2023). The most observed color was yellow, and the yellow-seeded varieties exhibit a wide range of applicability across various processing techniques, but the utilization of black-seeded types is rather more restricted. The production of black pigments or other chemicals during pigment synthesis may potentially confer advantages in terms of seed storability (Desta *et al*., 2022). The anthocyanin content of seed coats is significantly influenced by the color of the flowers. For example, white flowers are produced by soybean plants, while purple flowers increase protein and seed size (Jo *et al*., 2021; Akmalovna, 2022).

Yield associated traits: The number of pods per plant (NPP) varied among the varietal lines. NIBGE 39 exhibited the highest NPP with a mean value of 187.7 ± 7.72, whereas NIBGE 46 displayed the lowest NPP with a mean value of 5.3 ± 7.72. The season has no statistically significant impact on NPP (**Table 7**). The 100GW in varietal line varied between 7.7 ± 0.41g and 21.7 ± 0.41 g. In spring, NIBGE 25 and NIBGE 37 were shown significantly higher seed weights (100 grains) than control varieties Ajmeri, Faisal, Jack and Rawal in both summer and spring seasons. The average 100GW (g) in summer and spring seasons was not significantly different (Mann-Whitney, U=9207, p=0.07) (Table 7). The NIBGE 32 produced the highest seed weight per plant (SWP) in summer (22.0 g) as well as in spring (20.3 g) per plant. Moreover, NIBGE 18, and NIBGE 8 also produced higher yields than control varieties (Table 7). NIBGE 32 (336 ± 4.55) had the highest TGY, while NIBGE 22 (39 ± 4.55) had the lowest. (Table 7).

Table 7. Number of pods per plant (NPP), 100 Grains weight (100GW), and Seed weight per plant (SWP) of soybean lines tested during the spring and summer seasons of the year 2018.

Varieties	Number of pods per plant		100 Grains weight (g)		Seed weight per plant (g)	
	Spring	Summer	Spring	Summer	Spring	Summer
Ajmeri C	17.3 ± 7.72^{i-n}	17.3 ± 7.72^{i-n}	12.3 ± 0.41^{g-i}	13.3 ± 0.41^{fg}	10.7 ± 0.31^{n-p}	11.7 ± 0.31^{k-m}
Faisal C	37.7 ± 7.72^{f-i}	37.7 ± 7.72^{f-i}	11.3 ± 0.41^{i-l}	12.0 ± 0.41^{h-j}	13.4 ± 0.31^{i}	14.4 ± 0.31^{gh}
Jack C	12.0 ± 7.72^{k-n}	12.0 ± 7.72^{k-n}	15.0 ± 0.41^{de}	16.0 ± 0.41^{cd}	6.0 ± 0.31^{x-z}	6.0 ± 0.31^{x-z}
Rawal C	11.3 ± 7.72^{l-n}	11.3 ± 7.72^{l-n}	11.3 ± 0.41^{i-l}	12.0 ± 0.41^{h-j}	11.0 ± 0.31^{m-o}	12.0 ± 0.31^{kl}
NIBGE 1	37.7 ± 7.72^{f-i}	37.7 ± 7.72^{f-i}	13.3 ± 0.41^{fg}	14.0± 0.41^{ef}	9.7 ± 0.31^{qr}	10.0 ± 0.31^{p-r}
NIBGE 2	36.0 ± 7.72^{g-i}	36.0 ± 7.72^{g-i}	11.3 ± 0.41^{i-l}	12.0± 0.41^{h-j}	6.7 ± 0.31^{v-x}	7.0 ± 0.31^{u-w}
NIBGE 3	105.7 ± 7.72^{b}	105.7 ± 7.72^{b}	11.3 ± 0.41^{i-l}	11.7± 0.41^{i-k}	9.3 ± 0.31^{r}	10.3 ± 0.31^{o-q}
NIBGE 4	51.7 ± 7.72^{d-h}	51.7 ± 7.72^{d-h}	12.3 ± 0.41^{g-j}	13.0± 0.41^{f-h}	12.3± 0.31^{jk}	13.0 ± 0.31^{ij}
NIBGE 5	59.0 ± 7.72^{c-f}	59.0 ± 7.72^{c-f}	15.3 ± 0.41^{d}	16.0 ± 0.41^{cd}	13.0 ± 0.31^{ij}	13.7 ± 0.31^{hi}
NIBGE 6	51.7 ± 7.72^{d-h}	51.7 ± 7.72^{d-h}	7.7 ± 0.41^{p}	7.7 ± 0.41^{p}	6.7 ± 0.31^{v-x}	7.0 ± 0.31^{u-w}
NIBGE 7	41.3 ± 7.72^{e-i}	41.3 ± 7.72^{e-i}	8.0 ± 0.41^{p}	8.0 ± 0.41^{p}	6.3 ± 0.31^{w-y}	6.3 ± 0.31^{w-y}
NIBGE 8	33.3 ± 7.72^{h-k}	33.3 ± 7.72^{h-k}	11.0 ± 0.41^{j-m}	12.0 ± 0.41^{h-j}	16.0 ± 0.31^{e}	17.0 ± 0.31^{d}
NIBGE 9	21.3 ± 7.72^{i-n}	21.3 ± 7.72^{i-n}	11.0 ± 0.41^{j-m}	12.0 ± 0.41^{h-j}	14.3 ± 0.31^{gh}	15.0 ± 0.31^{fg}
NIBGE 10	21.3 ± 7.72^{i-n}	21.3 ± 7.72^{i-n}	8.0 ± 0.41^{p}	8.0 ± 0.41^{p}	5.0 ± 0.31^{aa}	5.0 ± 0.31^{aa}
NIBGE 11	45.0 ± 7.72^{f-i}	43.5 ± 7.72^{e-i}	9.5 ± 0.41^{no}	10.5 ± 0.41^{k-n}	6.5 ± 0.31^{v-y}	7.0 ± 0.31^{u-w}
NIBGE 12	15.7 ± 7.72^{i-n}	15.7 ± 7.72^{i-n}	11.3 ± 0.41^{il}	12.0 ± 0.41^{h-j}	10.3 ± 0.31^{o-q}	11.0 ± 0.31^{m-o}
NIBGE 13	69.7 ± 7.72^{cd}	69.7 ± 7.72^{cd}	9.3 ± 0.41^{no}	10.0 ± 0.41^{m-o}	11.0 ± 0.31^{m-o}	12.0 ± 0.31^{kl}
NIBGE 14	25.7 ± 7.72^{i-n}	25.7 ± 7.72^{i-n}	8.0 ± 0.41^{p}	8.0 ± 0.41^{p}	5.0 ± 0.31^{aa}	5.0 ± 0.31^{aa}
NIBGE 15	25.7 ± 7.72^{i-n}	25.7 ± 7.72^{i-n}	11.0 ± 0.41^{j-m}	12.0 ± 0.41^{h-j}	3.0 ± 0.31^{ac}	3.0 ± 0.31^{ac}
NIBGE 16	73.7 ± 7.72^{c}	73.7 ± 7.72^{c}	11.7 ± 0.41^{i-k}	12.0 ± 0.41^{h-j}	11.3 ± 0.31^{l-n}	12.3 ± 0.31^{jk}
NIBGE 17	33.7 ± 7.72^{h-j}	33.7 ± 7.72^{h-j}	13.0 ± 0.41^{f-h}	14.0 ± 0.41^{ef}	13.3 ± 0.31^{i}	14.7 ± 0.31^{fg}
NIBGE 18	32.3 ± 7.72^{h-l}	32.3 ± 7.72^{h-l}	9.0 ± 0.41^{o-p}	10.0 ± 0.41^{m-o}	18.0 ± 0.31^{c}	19.7 ± 0.31^{b}
NIBGE 19	33.0 ± 7.72^{h-k}	33.0 ± 7.72^{h-k}	11.3 ± 0.41^{i-l}	12.0 ± 0.41^{h-j}	6.7 ± 0.31^{v-x}	7.7 ± 0.31^{s-u}
NIBGE 20	60.0 ± 7.72^{c-e}	60.0 ± 7.72^{c-e}	7.7 ± 0.41^{p}	7.7 ± 0.41^{p}	5.3 ± 0.31^{z-aa}	5.3 ± 0.31^{z-aa}
NIBGE 21	20.3 ± 7.72^{i-n}	20.3 ± 7.72^{i-n}	15.0 ± 0.41^{de}	16.0 ± 0.41^{cd}	10.3 ± 0.31^{o-q}	11.3 ± 0.31^{l-n}
NIBGE 22	25.7 ± 7.72^{i-n}	25.7 ± 7.72^{i-n}	13.0 ± 0.41^{f-h}	14.0 ± 0.41^{ef}	6.0 ± 0.31^{x-z}	6.0 ± 0.31^{x-z}
NIBGE 23	29.0 ± 7.72^{i-m}	29.0 ± 7.72^{i-m}	10.3 ± 0.41^{l-n}	11.0 ± 0.41^{j-m}	5.3 ± 0.31^{z-aa}	5.3 ± 0.31^{z-aa}
NIBGE 24	43.0 ± 7.72^{c-i}	43.0 ± 7.72^{e-i}	13.3 ± 0.41^{f-g}	14.0 ± 0.41^{ef}	13.0 ± 0.31^{ij}	14.7 ± 0.31^{fg}
NIBGE 25	10.3 ± 7.72^{mn}	10.3 ± 7.72^{mn}	20.0 ± 0.41^{b}	21.7 ± 0.41^{a}	7.3 ± 0.31^{t-v}	8.0 ± 0.31st
NIBGE 26	32.7 ± 7.72^{h-l}	32.7 ± 7.72^{h-l}	9.3 ± 0.41^{no}	10.0 ± 0.41^{m-o}	5.3 ± 0.31^{z-aa}	5.3 ± 0.31^{z-aa}
NIBGE 27	11.3 ± 7.72^{l-n}	11.3 ± 7.72^{l-n}	12.0 ± 0.41^{h-j}	13.0 ± 0.41^{f-h}	10.3 ± 0.31^{o-q}	11.3 ± 0.31^{l-n}
NIBGE 28	32.7 ± 7.72^{h-l}	32.7 ± 7.72^{h-l}	11.3 ± 0.41^{i-l}	12.0 ± 0.41^{h-j}	4.8 ± 0.31^{aa-ab}	4.8 ± 0.31^{aa-ab}
NIBGE 29	12.7 ± 7.72^{j-n}	12.7 ± 7.72^{j-n}	12.0 ± 0.41^{h-j}	12.3 ± 0.41^{g-i}	4.0 ± 0.31^{ab}	4.0 ± 0.31^{ab}
NIBGE 30	16.3 ± 7.72^{i-n}	16.3 ± 7.72^{i-n}	9.0 ± 0.41^{op}	10.0 ± 0.41^{m-o}	4.0 ± 0.31^{ab}	4.0 ± 0.31^{ab}
NIBGE 31	35.7 ± 7.72^{g-i}	35.7 ± 7.72^{g-i}	11.0 ± 0.41^{j-m}	12.0 ± 0.41^{h-j}	7.0 ± 0.31^{u-w}	7.6 ± 0.31^{s-u}
NIBGE 32	37.3 ± 7.72^{g-i}	37.3 ± 7.72^{g-i}	15.0 ± 0.41^{de}	16.0 ± 0.41^{cd}	20.3 ± 0.31^{b}	22.0 ± 0.31^{a}
NIBGE 33	19.0 ± 7.72^{i-n}	19.0 ± 7.72^{i-n}	11.3 ± 0.41^{i-l}	12.0 ± 0.41^{h-j}	6.0 ± 0.31^{x-z}	6.0 ± 0.31^{x-z}
NIBGE 34	35.0 ± 7.72^{hi}	35.0 ± 7.72^{hi}	11.7 ± 0.41^{i-k}	12.0 ± 0.41^{h-j}	7.3 ± 0.31^{t-v}	8.1 ± 0.31st
NIBGE 35	9.7 ± 7.72^{mn}	9.7 ± 7.72^{mn}	13.0 ± 0.41^{f-h}	14.0 ± 0.41^{ef}	5.7 ± 0.31^{y-aa}	5.7 ± 0.31^{y-aa}
NIBGE 36	8.7 ± 7.72^{mn}	8.7 ± 7.72^{mn}	12.3 ± 0.41^{g-i}	13.0 ± 0.41^{f-h}	7.7 ± 0.31^{s-u}	7.7 ± 0.31^{s-u}
NIBGE 37	12.0 ± 7.72^{k-n}	12.0 ± 7.72^{k-n}	15.7 ± 0.41^{d}	17.0 ± 0.41^{c}	8.3 ± 0.31^{s}	10.0 ± 0.31^{p-r}
NIBGE 38	15.3 ± 7.72^{i-n}	15.3 ± 7.72^{i-n}	13.3 ± 0.41^{fg}	14.0 ± 0.41^{ef}	6.0 ± 0.31^{x-z}	6.0 ± 0.31^{x-z}
NIBGE 39	187.7 ± 7.72^{a}	187.7 ± 7.72^{a}	11.3 ± 0.41^{i-l}	12.0 ± 0.41^{h-j}	11.0 ± 0.31^{m-o}	11.7 ± 0.31^{k-m}
NIBGE 40	57.0 ± 7.72^{c-g}	57.0 ± 7.72^{c-g}	11.3 ± 0.41^{i-l}	12.0 ± 0.41^{f-h}	7.0 ± 0.31^{u-w}	7.7 ± 0.31^{s-u}
NIBGE 41	6.7 ± 7.72^{n}	6.7 ± 7.72^{n}	8.0 ± 0.41^{p}	8.0 ± 0.41^{p}	14.3 ± 0.31^{gh}	15.3 ± 0.31^{ef}
NIBGE 42	15.0 ± 7.72^{i-n}	15.0 ± 7.72^{i-n}	11.0 ± 0.41^{j-m}	11.3 ± 0.41^{i-l}	7.7 ± 0.31^{s-u}	7.7 ± 0.31^{s-u}
NIBGE 43	34.3 ± 7.72^{hi}	34.3 ± 7.72^{hi}	11.3 ± 0.41^{i-l}	12.0 ± 0.41^{h-j}	10.7 ± 0.31^{n-p}	11.3 ± 0.31^{l-n}

NIBGE 44	12.0 ± 7.72^{k-n}	12.0 ± 7.72^{k-n}	13.0 ± 0.41^{f-h}	14.0 ± 0.41^{ef}	5.3 ± 0.31^{z-aa}	5.3 ± 0.31^{z-aa}
NIBGE 45	7.0 ± 7.72^{n}	7.0 ± 7.72^{n}	13.3 ± 0.41^{fg}	14.0 ± 0.41^{ef}	14.3 ± 0.31^{gh}	15.4 ± 0.31^{s-u}
NIBGE 46	5.3 ± 7.72^{n}	5.3 ± 7.72^{n}	10.3 ± 0.41^{l-n}	11.0 ± 0.41^{j-m}	7.7 ± 0.31^{s-u}	7.7 ± 0.31^{s-u}

Values before the ± are the means of the sample, and values after ± are the Standard error of the mean. Means with the same letter are not significantly different a p<0.05.

The harvest Index (HI) of three varieties NIBGE 8, NIBGE 32, and NIBGE 41 was higher than that of four control varieties. Although the HI of NIBGE 18 and NIBGE 45 were close to the same of control varieties they produced higher yields in the summer and spring seasons. Control varieties had HI ranging from 2.4 (Jack) to 5.4 (Faisal), with an average HI of 4.2 ± 1.49 (Figure 2) In contrast, varietal lines had an average HI of 3.2 ± 1.52. Among the test varieties, only five had HI greater than or equal to Faisal, the control variety with the highest HI (Figure 2).

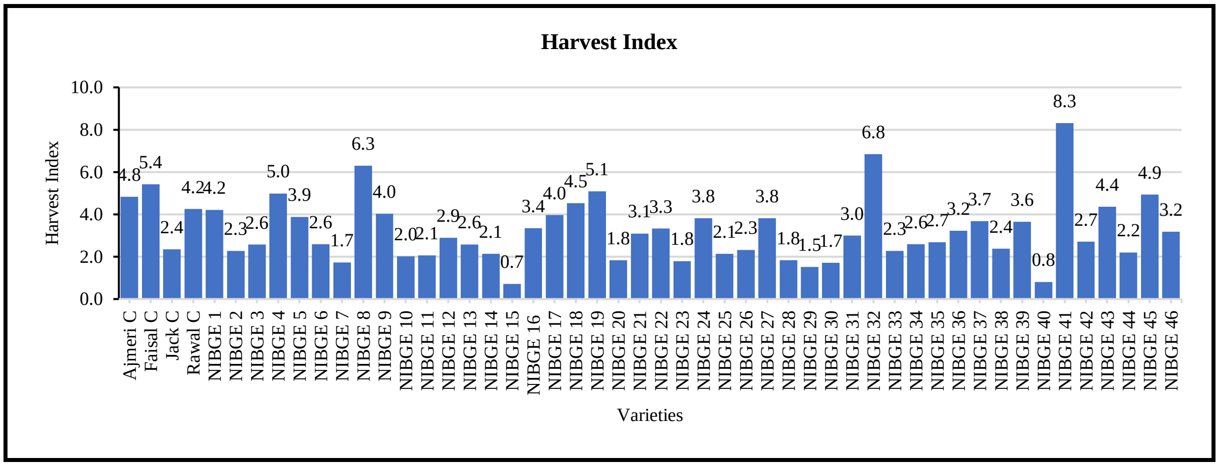

Figure. 2 Harvest index (HI) of soybean varietal lines tested during the spring and summer seasons of the year 2018

All varieties produced comparatively higher yields in the summer season. Among the test varieties, three varieties produced more than 18% of the yield compared to the highest yield produced by the Control variety Faisal. In the summer season, NIBGE 32 produced a 53% higher yield than Faisal (Control variety) followed by NIBGE 18 (36%) and NIBGE 8 (18.3%). Whereas NIBGE 45 and NIBGE 41 revealed only 6% higher yield than the control variety Faisal. Soybean yield is highly dependent on the number of pods produced, which is an indicator of the plant's health. The NPP results soybean varieties Setiawan *et al*., (2023), highlighting the significance of this finding. Studies by Pedersen & Lauer, (2004) showed that adjusting sowing dates can increase pod and seed quantity, and Adetokunbo *et al*., (2019) also highlighted the importance of pods and seeds per plant in soybean seed production. The wide range in 100 GW weight emphasizes the genetic diversity within soybean varieties. Comparing the average 100 GW during the summer and spring seasons revealed no significant difference. This finding suggests that seasonal variations did not exert a significant influence on the 100 GW of soybean varieties under semi-arid conditions. The obtained seed weight results are supported by Badiaraja *et al*., (2021) as well as Saha & Islam, (2022). Their findings show significant differences in seed yields between cultivars, which is consistent with the current study's focus on the effect of varietal lines on seed weight per plant. Furthermore, Zuyasna *et al*., (2023) documented mean seed weight per plant across various cultivars, providing further evidence that cultivar selection influences seed weight per plant. This stability in seed weight across seasons could be useful information for farmers, allowing them to plan sowing schedules without excessive concern for significant fluctuations in seed weight due to changing environmental conditions. In addition, the consistency of seed weight across seasons suggests a certain level of resilience in these varieties, which is important information for agricultural planning and decision-making. As a TGY measure of the crop, yield can help decision makers by enhancing and supporting crop management (Wei & Molin, 2020). Harvest index (HI) is a way to measure how photosynthate splits up. When the crop harvest index goes up, it means that the crops' economic value goes to a certain amount (Asefa, 2019). Dry stem weight changes were linked to HI variations, and late sowing increased HI (Kawasaki *et al*., 2018). **Comparison of Seed production with control varieties:** A comparison of seed production per plant was performed among the evaluated varieties, with the Faisal variety serving as the control given to its higher performance throughout the spring season. The results show that NIBGE 8, NIBGE 9, NIBGE 18, NIBGE 32, NIBGE 41, and NIBGE 45 performed better than the

Ajmeri variety (Figure 3a). During the summer a comparison of seed production per plant was performed across the examined varieties, with the Faisal variety serving as the control given to its superior performance. The results show that NIBGE 8, NIBGE 9, NIBGE 17, NIBGE 24, NIBGE 32, NIBGE 41, and NIBGE 45 performed better than the Ajmeri variety (Figure 3b).

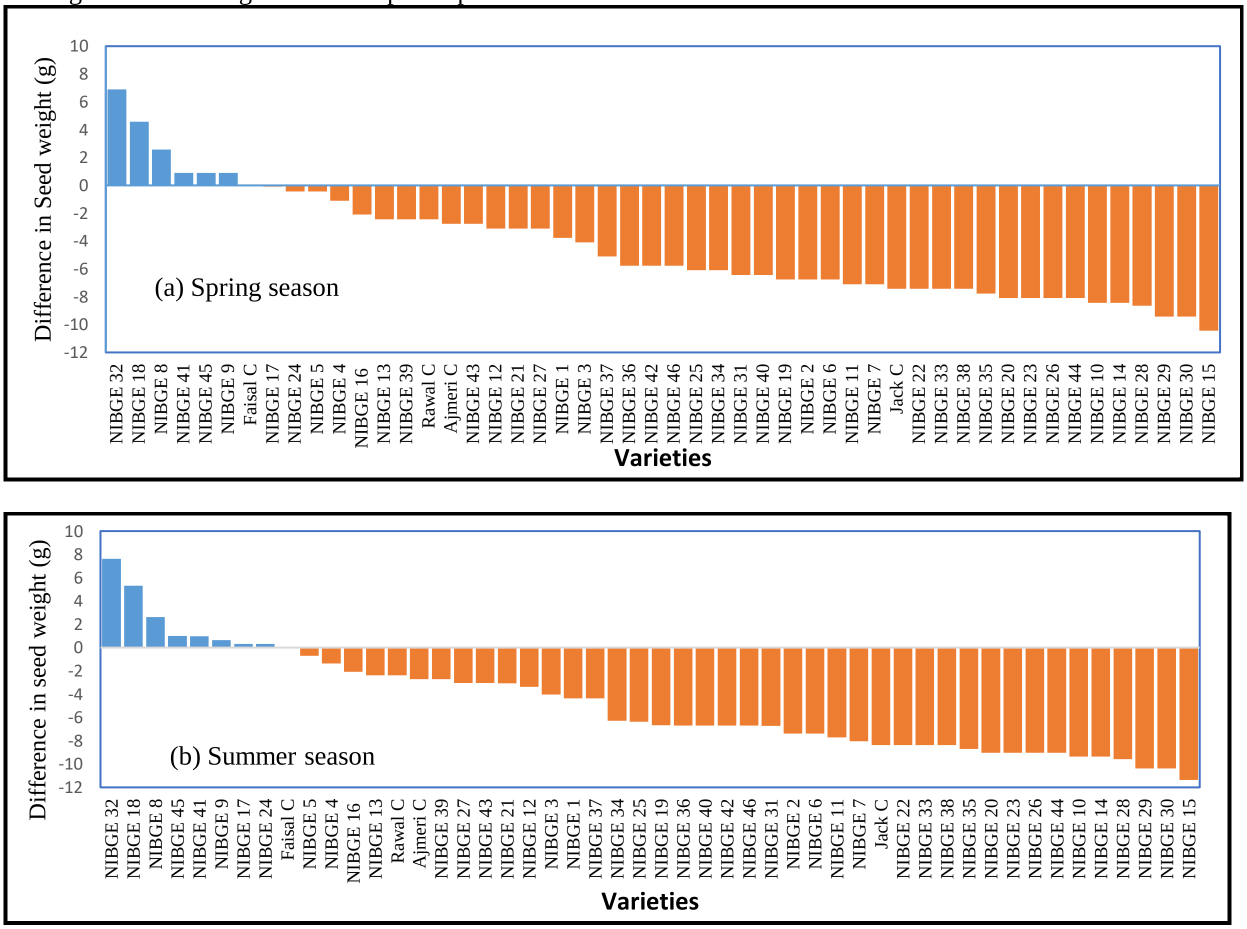

Figure. 3. (a&b) Difference of the seed production per plant (g) compared with the control variety Faisal in th**e** summer season**.**

Cluster analysis of soybean varietal lines: Cluster analysis is a tool for sorting data according to similarities (Rani *et al.*, 2023). Based on all morphological and yield characteristics, the analyzed varietal lines fallen seven clusters. The largest cluster contained fifteen genotypes, including two check varieties, Faisal, and Jack. NIBGE 32 stands out from all other varietal lines in cluster analysis due to its unique morphological and yield characteristics. Mainly significant are its germination percentage (G%), plant population at harvesting (PPH), leaf area (LA), 100-grains weight (100GW), seed weight per plant (SWP), and total grain yield (TGY). NIBGE 32 appears to be different from all varieties and exhibits a relatively close similarity with the cluster of NIBGE 39 and NIBGE 3. While cluster analysis can be useful for sorting data and identifying similarities, it may not provide enough information for comprehensive agricultural planning and decision-making as it only considers morphological and yield characteristics without accounting for other important factors such as disease resistance or environmental adaptability.

Conclusion: Our study concludes that there is a notable diversity in physical characteristics across six different varietal lines when examining various agricultural factors under the specific agro-climatic circumstances of Tandojam. The observed phenotypic relationships among Germination Percentage, Seed Weight per Plant, and 100-grain Weight highlight the important function of these parameters in selecting varietal lines. The distinguishing factor of our study lies in its particular emphasis on the conditions in Tandojam, which offers distinctive perspectives on soybean cultivation in this area. The varietal lines that have been identified, including NIBGE 8, 9, 18, 32, 41, and 45, consistently demonstrate greater yields in different seasons, suggesting their strong and consistent performance. Our research presents these promising soybean lines as prospective options for production in various agroecological zones in the Sindh region. The differentiation from prior research highlights the practical usefulness of our discoveries and suggests the need for additional on-site experimentation in many weather circumstances, providing vigorous knowledge for the scientific community and improving soybean cultivation methods in the area.

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