



Faculty of Agriculture, University of Poonch Rawalakot



Check for updates

Jammu Kashmir Journal of Agriculture

ISSN: 2958-3756 (Online), 2958-3748 (Print)

<https://jkjagri.com/index.php/journal>

STUDIES ON ESTIMATION AND VARIABILITY OF GRAIN YIELD AND HUSK YIELD IN ISPAGHOL (*PLANTAGO OVATA* FORSK.) VARIETIES UNDER SEMI-ARID CONDITION OF SINDH

Waheed Ali Khaskheli^{1,2}, Bakht Nisa Mangan^{1*}, Aijaz Ahmed Soomro¹, Inayatullah Rajpar¹, Muhammad Siddique Lashari¹

¹ Sindh Agriculture University, Tandojam, 70060, Pakistan.

² Agriculture Extension Wing of Agriculture Supply & Prices Department Govt. of Sindh, Pakistan.

ABSTRACT

Sindh is the main hub of Ispaghol cultivation due to its sandy soils and dry winter climate for its expansion. However, scanty information is available concerning to morphology and genetic variability of Ispaghol genotypes. Focusing these outlines, a study was conducted during 2023-24 at Sindh Horticulture Research Center, Mirpurkhas (Sindh) Pakistan. Under this study, it was tried to screen out the high-yielding variety for improving Ispaghol yield in Sindh. Results of present study indicated that there was a great variability for morphological, physiological, yield parameters Ispaghol genotypes under Mirpurkhas conditions for studied year (2023-24). The mean performance of these genotypes for all the morphological and yield attributing characters showed significant variation among the different genotypes for different parameters. The main conclusion arising from this study is that the on the basis of seed yield per plant IELF-1, IELF-2, IELF-3 and IELF-4, can be chosen for commercial cultivation in Sindh conditions over to Gulabi. However, overall analysis of all the germplasm in terms of morpho-physiological and yield attributing parameters clearly reveals that the IELF-1 and IELF-2 were found to be the best in the agro-climatic condition of studied location. Thus, IELF-1 and IELF-2 can be taken for the further investigation for commercial Ispaghol cultivation by the breeder. Therefore, it may be recommended for commercial cultivation of ispaghol under Indus Delta Zone of Pakistan.

Keywords: Ispaghol; Grain Yield; Husk Yield.

Corresponding Author: Bakht Nisa Mangan

Email: nisasau@gmail.com, bmmangan@sau.edu.pk

Article history

Received: October 28th, 2025

Revised: December 20th, 2025

Accepted: December 26th, 2025

INTRODUCTION

Ispaghol (*Psyllium*) is the most important crop for medicinal and industrial uses. It is cultivated primarily for their seed, husk, and mucilage, which have widespread applications in medicine, diet, and industry (Deokar, 2016; Tyagi et al., 2016), both seed and husk are used to treat constipation, gastrointestinal irritation, and to regulate cholesterol and diabetes. Clinical evidence confirms that Isapgol moderates postprandial glucose levels, supporting diabetes management, while its high fiber content enhances satiety and aids in weight control. It is also used in curing of chronic dysentery, diarrhea, duodenal ulcer, constipation and piles (Arya et al., 2021). Ispaghol is successfully growing in different climatic zones of Sindh province (Shah,

2020) and is the main hub of Ispaghol cultivation due to its sandy soils and dry winter climate for its expansion (Akhtar et al., 2019; Arya et al., 2021).

Being a high-value medicinal crop, its cultivation area (estimated under 6,000 acres) and production (only 600-800 kg ha⁻¹) in Pakistan is very small compared to India (up to 1.5-2 t ha⁻¹) (Amanullah et al., 2016; PFI, 2018; Sher & Khatoon, 2018). The major factors responsible for low crop yield include the use of low-yielding indigenous varieties, poor quality seed, and limited availability of improved genotypes. Improving Ispaghol yield in Sindh requires strategies: adoption of improved varieties for high-yielding (Bafra et al., 2011) and disease-tolerant genotypes (e.g., exotic varieties), sowing on most suitable sowing time

(Ahirwar et al., 2015) and method (Kang, 1993), explore bio-fertilizers (Azotobacter, PSB) to enhance nutrient uptake, applying balanced fertilization & irrigation, by effective weed/pest management, timely harvesting to prevent losses, incorporate farmyard manure (FYM) to improve soil structure and water retention, use mulching to conserve moisture in dry Sindh areas, introducing mechanized harvesting and threshing to reduce losses (Anwar & Rabia, 2017).

Introducing and adopting exotic varieties is a strategic approach to achieve higher yield and improved productivity in agriculture (Jat et al., 2015; Kirti & Arya, 2019). Exotic varieties are often developed through advanced breeding programs and possess superior traits such as higher yield potential, better adaptability to diverse environments, tolerance to biotic and abiotic stresses, and improved quality characteristics. Exotic varieties should be introduced and adopted because indigenous varieties often have lower yield potential and limited responsiveness to improved agronomic practices (Repsiene, 2001; Rehana et al., 2012). While local varieties are well adapted to traditional conditions, they may not meet the increasing demand for higher productivity and market competitiveness. In contrast, exotic varieties are developed for superior yield, uniformity, and better quality traits, making them more suitable for commercial cultivation (Lockyer & Nugent, 2017). Moreover, introducing exotic varieties promotes genetic diversity, supports sustainable agricultural intensification, and contributes to food and nutritional security under changing climatic conditions. Therefore, replacing or supplementing

low-yielding indigenous varieties with high-yielding exotic ones can significantly enhance crop production, improve farmers' income, and support sustainable agricultural development (Hazra et al., 2008; Jat et al., 2015; Khan et al., 2018). Their adoption can help overcome the yield limitations of local cultivars, meet increasing market demand, and enhance farmers' income. When properly evaluated under local agro-climatic conditions and supported by suitable management practices, exotic varieties can significantly contribute to sustainable crop production, food security, and overall agricultural development.

MATERIALS AND METHODS

Plant materials and location

A study was organized during 2023-24 at Sindh Horticulture Research Center, Mirpurkhas (Sindh) Pakistan to find out the high-yielding variety for improving Ispaghul quality and yield under semi-arid conditions of Sindh. The experimental was conducted at Sindh Horticulture Research Center, Mirpurkhas, lying on the 25°31'39.3"N 69°00'50.6"E with 55–60 meters elevation above sea level which is located in the southeastern quadrant of Sindh (Figure 2). It lies in the semi-arid climate with hot summers (up to 45 °C) and mild winters (rarely below 6 °C). Average rainfall is 150-250 mm annually, concentrated in monsoon (July–September). Soils are highly fertile Alluvial, clay-loam to sandy-loam structure, making it Southern Irrigated Plain Agro-Ecological Zone (AEZ) of Pakistan part of the Lower Indus Basin (Anwar & Rabia, 2017; Brendan, 2024; Jour et al., 2021; Pervez et al., 2010; Rehana et al., 2012; Uzma et al., 2010).

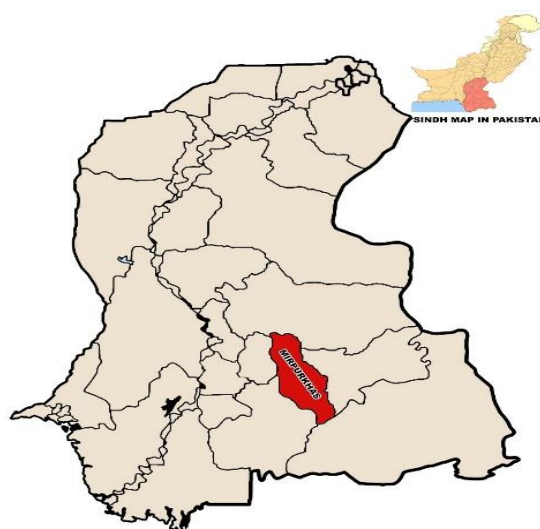


Figure 1: The geographical map representing the studied experimental field.

The experiment was laid out in Randomized Complete Block Design (RCBD), replicated thrice. For good crop stand, soil was crosswise plowed with a five-share plough followed by levelling to get fine tilth. After conducting soaking dose, in conditioned soil, ploughing was done with Disc harrow followed by rotavator. Seed of four exotic genotypes: IELF-1, IELF-2, IELF-3, IELF-4 (received from Ayoub Agricultural Research Institute, Faisalabad) and Local Check (*Gulabi*) were sown on 15th November, with 2-2.5 kg acre⁻¹ seed rate through drilling in 9 cm row length at 30 cm spacing apart rows and spaced 5cm apart for better crop management. Nitrogen in two

splits (first at the time of land preparation and second at the time of second irrigation) and a full dose of Phosphorus was applied. Three irrigations at 20, 50 and 80 days after sowing and three weeding at 15, 40 and 80 days after sowing were conducted.

Weather variables

An eye was kept to check four basic meteorological indicators minimum temperature (°C), maximum temperature (°C), relative humidity (%) and rainfall (mm) during growing seasons of the experimental site. The data was collected from National Meteorological Observatory station Tandojam and presented in the Figure 2.

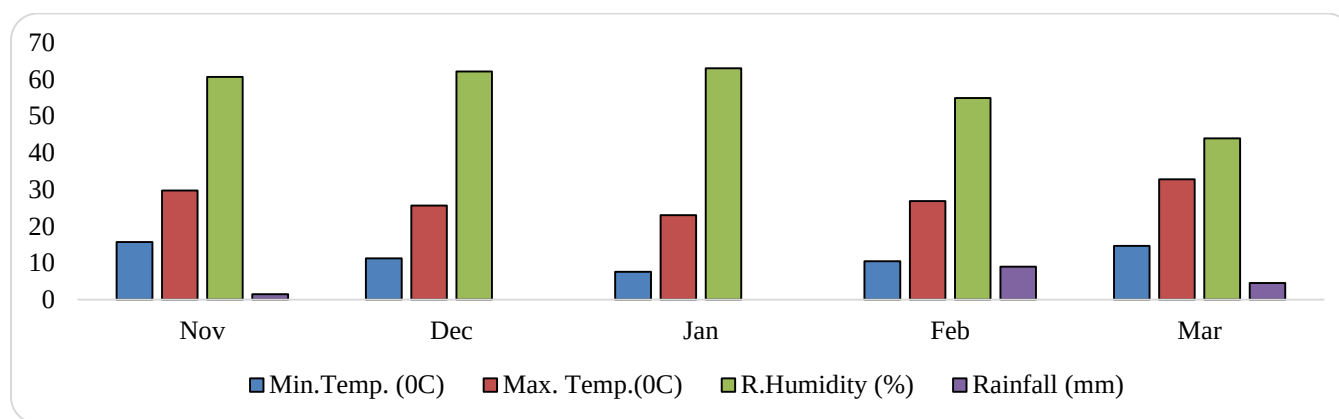


Figure 2: Weather variables of growing season of experimental location.

Soil analysis

Soil is a natural body with a wide range of physical, chemical, and biological characteristics that determine its fertility and productivity of soil. To check soil physico-chemical properties like pH, EC (dS m⁻¹), organic matter (%), total N (%), available P (mg kg⁻¹), extractable K (mg kg⁻¹) soil samples were collected randomly at the depths of 0-15 cm from experimental site during studied year with the help of stainless steel auger.

Growth and yield attributes

The crop was harvested in the month of March when the spike turned reddish-brown colour and lower leaves dried up, at the time of maturity five fully mature plants were randomly selected and tagged from each genotypes as a sample for collecting data of different yield attributing characters viz. plant height (cm), tillers (m⁻²), days to maturity, spike length (cm), spikes plant⁻¹, seeds spike⁻¹, seed index (1000-grain wt., g), seed yield plant⁻¹, seed yield (kg ha⁻¹) and husk yield (kg ha⁻¹). For the observations of seed yield (kg ha⁻¹) and husk yield (kg ha⁻¹), seed was harvested from net plot area (15 m²) and weighed. The husk from the seeds was separated and weighed separately. The

yield hectare⁻¹ was calculated by using the net plot yield and the husk recovery was (Tyagi et al., 2016).

Statistical analysis

Three samples from each genotypes were analysed from the all replications during studied years, the sample results were reported as the mean ± standard deviation (SD). Means were compared using Tukeys' HSD test (P < 0.05). To test the significant differences among means of various attributes, analysis of variance (ANOVA) was employed to measure significant differences between and within genotype (Gomez, 1984).

RESULTS

Under this study, it was tried to screen out the adoption of high-yielding exotic varieties for improving Ispaghool yield in Sindh. The mean performance of these exotic genotypes and local check for all the morphological, yield and quality attributing characters are presented in subsequent tables (Table 2, and 3 and Figure 3).

Physical characteristics of Soil

Physical characteristics of soil is presented in Table 1, soil was Sandy Loam in texture, with 1.5% OM, according to

the findings. Chemically, soil had 8.5 pH with 0.59 nitrogen%, 0.037 mg kg⁻¹ phosphorus, 2.33mg kg⁻¹ potassium. Generally, electrical conductivity (EC) was 2.33 EC (dS m⁻¹) during studied year.

Weather variables

According to the data of both growing seasons (Figure 2), the mean maximum temperature ranged was between 23-

34°C, while the mean minimum temperature was varied from 7-16°C. The total rainfall received during the season was 1.5 mm. Relative humidity remained moderate, averaging 63%, which created favorable conditions for crop growth. The average sunshine duration was about 10.5 hours per day, ensuring adequate solar radiation for photosynthesis.

Table 1: Physical characteristics of experimental field.

Location	Depth (cm)	Texture	pH	EC (dS m ⁻¹)	OM (%)	Total N (%)	P (mg kg ⁻¹)	K (mg kg ⁻¹)
Horticulture Research Center, Mirpurkhas	0-15	Sandy Loam Soil	8.5	2.33	0.9	0.59	0.037	2.33

Morphological Parameters

Height of plants was ranged from 28.6 to 32.0 cm with average mean value of 30.3 cm, the Coefficient of variation of varieties for plant height was 39% (Table 2). The data revealed that amongst four varieties under study, the tallest plant (~32.0 cm) was IELF-2 and the shortest was Gulabi with ~28 cm plant height as compared other varieties (Table 3). The maximum number of tillers plant⁻¹ was exhibited in the variety IELF-2 (7.9) followed by

IELF-1 (7.1) while as minimum value was observed in the variety Gulabi (5.1) during the experiment (Table 3). The C. Variation for tillers plant⁻¹ was 39.9% during studied year. The variety IELF-1 got more days (132) to get matured as compared the remaining varieties, while as Gulabi was early maturity with 125 days. Matureness of tested varieties was ranged from 100-132 days with average mean value of 115. The Coefficient of variation for crop maturity was 49% (Table 2).

Table 2: Mean ± SE of morphological and yield characters of ispaghol varieties.

Yield Parameters	Mean	Range	CV%	ANOVA
Plant height	30.30 ± 0.15	28.6-32.0	39.9	*
Tillers (m ⁻²)	6.15 ± 1.11	5.1-7.9	55.59	**
Days to maturity	115 ± 1.34	100-132	49.9	**
Spike length(cm)	4.02 ± 0.99	4.97-5.34	77.99	NS
Spikes plant ⁻¹	27.37 ± 1.70	22.4-38.7	69.07	NS
Seeds spike ⁻¹	85.00 ± 4.10	85.0-98.9	60.57	**
Seed Index (g)	2.17 ± 0.12	1.98-2.26	75.12	***
Seed Yield plant ⁻¹	4.66 ± 0.49	4.6-5.9	36.02	***
Seed Yield (Kg ha ⁻¹)	1152.63 ± 2.60	898.2-1275.7	71.00	***
Husk Yield (Kg ha ⁻¹)	248.0 ± 6.1	170.5-337.0	82.43	**

Ispaghol variety IELF-1 produced longest spike (5.35 cm) and showed stability for this morphological trait as compared to remaining varieties and Gulabi and variety IELF-3 (±4.97 cm) during studied year (Table 3). Range for spike length was from 4.98 to 5.35 cm with average mean value of 4.02 cm. The Coefficient of variation of varieties for spike length was 77% (Table 2). During the studied year the range for spikes plant⁻¹ from 22.4 to 38.7 with average mean value of 27.37. The Coefficient of variation for spikes plant⁻¹ was 69% (Table 2). The maximum number of spikes

plant⁻¹ (38.7) was recorded for IELF-2 variety followed by IELF-1 (32.1), while the minimum number of spikes plant⁻¹ was observed in Gulabi (22.4).

Yield Parameters

Seeds spikes⁻¹ was ranged from 85.0 to 98.9 with average mean value of 85.0 with 60% coefficient of variation for seeds per spikes⁻¹ (Table 2). As shown in Figure 3, the maximum number of seeds spikes⁻¹ was found in exotic varieties as compared to Gulabi during growing season. The highest total seed yield (1275.6 kg ha⁻¹) weighted from

variety IELF-1 followed by IELF- 2 during while the lowest yield was recorded by Gulabi (898.2 kg ha⁻¹) during the growing season. Range for seed yield was from 898.2 to 1275.7 kg ha⁻¹ with 71% Coefficient of variation (Table 2, Figure 3). According to findings, the husk yield has recorded significantly maximum (170.5 to 337.0 kg ha⁻¹) in

ispaghol varieties with mean value of 248 kg ha⁻¹ while as the lower seed and husk was recorded from local Gulabi. The Coefficient of variation of for husk yield ha⁻¹ was 82% (Table 2). Husk recovery, as revealed from ANOVA suggesting the existence of high genetic variability among different genotypes for the trait studied.

Table 3: Comparison of ispaghol varieties for quantitative parameters.

Ispaghol Varieties	Plant height (cm)	Tillers plant ⁻¹	Days to Maturity	Spike Length (cm)	Spikes plant ⁻¹
IELF-1	31.14 ± 3.05	7.1 ± 0.08	132 ± 20.15	5.35 ± 0.14	32.1 ± 1.05
IELF-2	32.01± 1.0	7.9 ± 0.57	123 ± 30.01	5.12 ± 0.84	38.7 ± 0.21
IELF-3	29.11± 1.30	6.7± 1.1	110 ± 20.11	4.98 ± 1.12	27.7 ± 1.1
IELF-4	31.05 ± 0.05	6.9 ± 0.27	100 ± 16.01	5.07 ± 1.22	25.9 ± 0.02
Gulabi	28.60 ± 0.02	5.1± 0.22	125 ± 25.37	4.97 ± 0.08	22.4 1.1

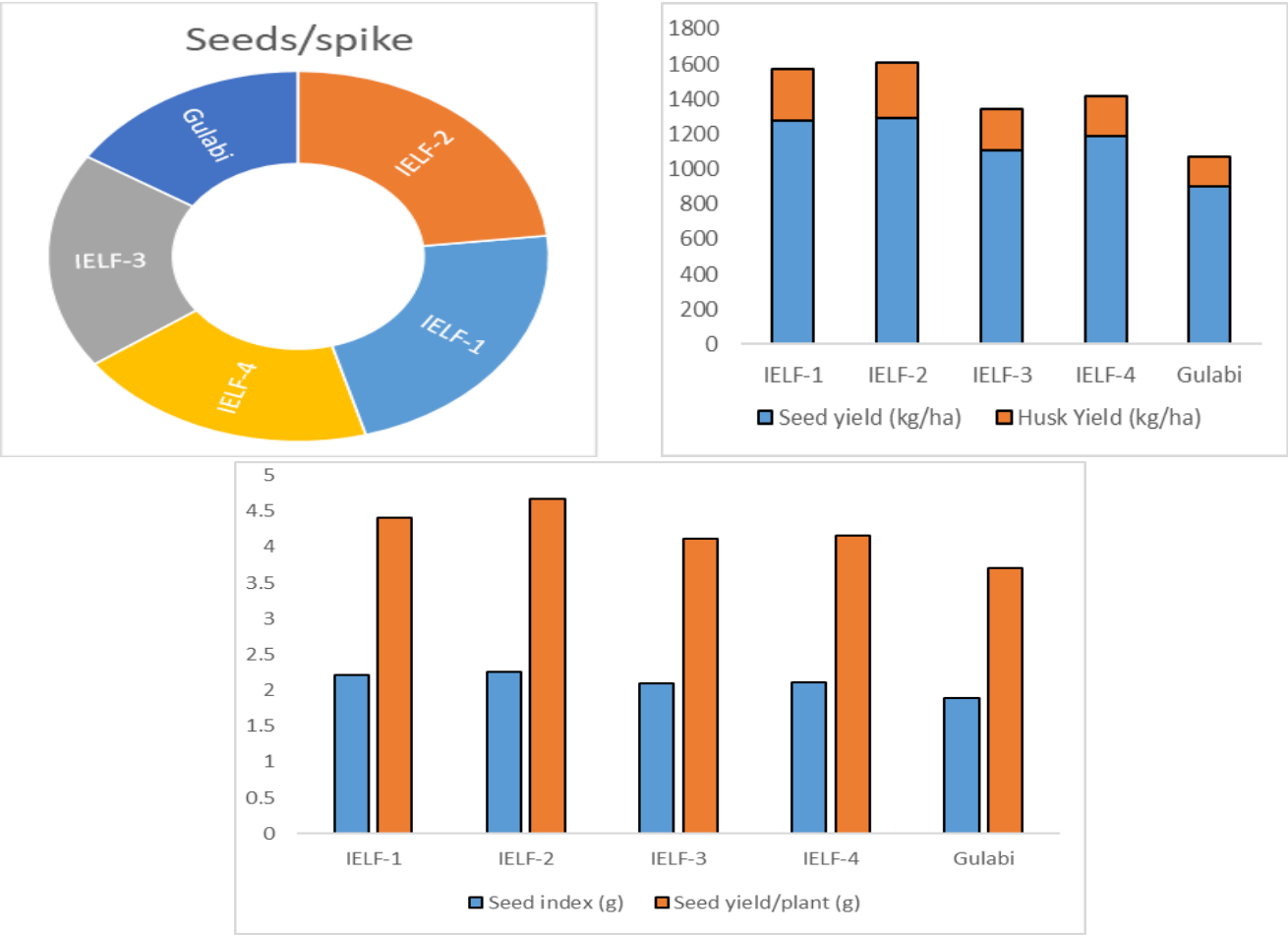


Figure 3. Comparison of ispaghol varieties for qualitative parameters.

Thousand seed weight (seed index), which is very important yield component, showed variation among the varieties. It ranged between 1.98 g to 2.26g with average mean 2.17g (Table 3, Figure 3). The lowest 1000 (thousands) seeds weight was recorded in Gulabi (1.98 g). The Coefficient of

variation for seed index was 65% (Table 2). According to the findings presented in Figure 3 and Table 2, varieties promising better seed yield plant⁻¹ ranging from 4.6 to 5.9 g plant⁻¹ with average mean value of 4.66g for studied year. The Coefficient of variation of ispaghol varieties for seed

yield plant⁻¹ was 75 % (Table 2).

DISCUSSION

Ispaghol is commercially an important crop with different uses. However, scanty information is available concerning to morphology and genetic variability of Ispaghol and its exotic genotypes. Sindh is the main hub of Ispaghol cultivation due to its sandy soils and dry winter climate for its expansion. Focusing these outlines, a study was conducted during 2023-24 at Sindh Horticulture Research Center, Mirpurkhas (Sindh) Pakistan. Under this study, it was tried to screen out the high-yielding exotic varieties for improving Ispaghol yield in Sindh. According to the results of present study that, there was a great variability for morphological (Table 3) and yield parameters (Figure 3) in Ispaghol genotypes. The mean performance of these Ispaghol genotypes for all the morphological and yield attributing characters are presented in subsequent tables, showed significant variation among the different genotypes for different parameters. This type of variance between various genotypes in Ispaghol for different characters have also been reported by (Reager et al., 2017).

The relationship between soil and Ispaghol is very important because soil characteristics directly affect its growth, yield, and husk quality (Nagaraju, 2018; Rajesh et al., 2021). According to findings, studied soil had Sandy Loam texture (Table 1), which refers to the relative proportion of sand, silt, and clay particles in soil. The type of texture influences soil structure, porosity, bulk density, and water-holding capacity. Organic matter content also plays a crucial role in improving water retention, aggregate stability, and fertility level of soil, 2-5% availability of OM in soil are considered as fertile soil for crops (Ahirwar et al., 2015). Studied soil containing 0.9% OM, which shows the deficiency of essential elements in soil. Pakistan and other South Asian regions, many cultivated soils have less than 1% OM, which is considered very low, so organic amendments (manure, compost, green manuring) are strongly recommended (Ali, 2017; Ladjevardi et al., 2015). Chemically, soil was with 8.5 pH which reflects the soil's ability to hold and exchange essential nutrients (Hazra, 2008). In studied soil, total nitrogen% was 0.59, 0.037 and 2.33 mg kg⁻¹ phosphorus and potassium were recorded respectively. Generally, electrical conductivity (EC) was 2.33 (dS m⁻¹) during studied year. Electrical conductivity (EC) of soil tells about the level of soluble salts or salinity so soil was non saline. According to our soil study findings, the soil was found to be physically and chemically suitable for Ispaghol cultivation.

The atmospheric conditions influence crop growth, soil processes, and overall ecosystem functioning. The most

important variables include temperature (°C), rainfall (mm), relative humidity (%), and day length (h.m). Temperature regulates plant metabolic activities, while rainfall is the primary source of soil moisture and determines water availability for crops. Relative humidity influences evapotranspiration and pest or disease incidence, whereas day length directly affects photosynthesis and plant development. Together, these weather variables provide a comprehensive understanding of the climatic conditions of a region, which is essential for agricultural planning, crop selection, and management practices (Omidbaigi & Mohebbi, 2012; Patel & Borad, 2016). Overall, the prevailing weather conditions at experimental location were favorable for crop establishment and growth, with suitable ranges for field Ispaghol production (Figure. 2).

According to the result presented in Table 3 that amongst five genotypes under this study, the tallest plant (~32 cm) was IELF-2 and the shortest was Gulabi with ~28 cm plant height. This variation might be due to genetic constituents of genotypes, healthy root development and agro-climatic conditions. Besides these, the greater availability of nutrients in soil due to integrated fertilizer application through inorganic and organic sources might possibly have enhanced meristematic activity leading to increased plant height and dry matter accumulation (Table 1). The mean performances between various genotypes of Ispaghol for number of tillers plant⁻¹ was ~6 with range 5.1 to 7.9 (Table 2). These findings were also supported (Hendry & Daulay, 1992). The ispaghol genotype IELF-1 got more days (132) to be matured as compared the remaining exotic genotypes, while as Gulabi was early maturity (125 days) variety over all tested material during studied year. The mean performances between various genotypes in Ispaghol for days taken to maturity have also been reported (Dubey et al., 2009). This might be due to individual varietal characters.

Exotic genotype IELF-1 produced longest spike (5.35 cm) and showed stability for this morphological trait as compared to remaining genotypes during studied year (Table 3). Similar results in case of spike length was also reported by Dubey et al. (2009). The maximum number of spikes plant⁻¹ (38.7) was recorded for IELF-2 genotype followed by IELF-1 (32.1). The improvements in yield attribute characters are correlated with improved cultural practices, management and balanced nutrient application (Rajesh et al., 2021; Sangan et al., 1992; Sharma & Garg, 2002; Sharma, 2004; Sharma & Ratnoo, 2013; Nagaraju, 2018).

The mean performances between various genotypes in Ispaghol for seeds spikes⁻¹ has also been reported by Dubey et al. (2009). As shown in Figure 3, the great variability for

seeds spikes⁻¹ was found in genotypes during growing season. The highest total seed yield (1275 kg ha⁻¹) weighted from ispaghol genotype IELF-2 while the lowest yield was recorded by Gulabi (898 kg ha⁻¹) during studied year (Table 2, Figure 3). The husk yield has recorded significantly maximum (170.5 to 337.9 kg ha⁻¹) in five genotypes with mean value of 248 kg ha⁻¹. The maximum husk yield might be due to higher plant population per unit area and adequate supply of organic and inorganic fertilizer and FYM to plants in balanced proportion increased seed and husk yield (Amanullah et al., 2016; Thanki & Talati, 1983). The increased seed and husk yield might be due to better nutritional status of the crop in the soil as evidenced by their uptake in the plant (Bafra et al., 2011; Jadhav et al., 2008). The optimal availability of OM and fertility level with good management, may have accelerated various physiological processes in the plant, resulting in increased growth and yield parameters, as well as increased seed and husk yield (Jain & Paul, 2011; Sharma & Ratnoo, 2013; Zhang et al., 2019). The differences in number of spikes per plant, number of seeds per spike and seed index in different genotype might be due to variation in germplasm, proper vegetative development and also for differences in soil and agro-climatic condition. The higher yield of promising genotypes might be due to higher number of branches, which leads to the production of a greater number of spikes per plant that directly affect the production of higher seed yield (Beniwal et al., 2007; Bafra et al., 2011; Jadhav et al., 2008). Thousand seed weight (seed index), which is very important yield component, showed variation among the genotypes. It ranged between 1.98 g to 2.26g with average mean 2.17g in both years.

CONCLUSION

The main conclusion arising from this study is that the on the basis of seed yield per plant IELF-1, IELF-2, IELF-3 and IELF-4, can be chosen for commercial cultivation in Sindh conditions over to Gulabi. However, overall analysis of all the germplasm in terms of morpho-physiological and yield attributing parameters clearly reveals that the IELF-1 and IELF-2 were found to be the best in the agro-climatic condition of studied location. Thus, IELF-1 and IELF-2 can be taken for the further investigation for commercial Ispaghol cultivation by the breeder. Therefore, it may be recommended for commercial cultivation of ispaghol under Indus Delta Zone of Pakistan.

CONFLICT OF INTEREST

The authors declare no conflict of interest

ACKNOWLEDGMENTS

The authors are grateful to Ayoub Agricultural Research Institute, Faisalabad for providing exotic genotypes of Isbaghol.

AUTHOR'S CONTRIBUTION

Waheed Ali Khaskheli, was involved in investigation, data collecting and writing of the first draft of the manuscript. Muhammad Siddique Lashari was involved in reviewing and editing. Bakht nisa Mangan, supervised the study.

REFERENCES

- Anwar, H. and Rabia, B. (2017) 'Impact of climate change on crops' productivity across selected agro-ecological zones in Pakistan', *The Pakistan Development Review*, 56(2), pp. 163–187.
- Ali, S., Hayat, R., Begum, F., Bohannan, B., Inebert, L. and Meyer, K. (2017) 'Variation in soil physical, chemical and microbial parameters under different land uses in Bagrot Valley, Gilgit, Pakistan', *Journal of the Chemical Society of Pakistan*, 39, pp. 97–110.
- Amanullah, M.A., Khetran, L.A., Badani, N., Rahojo, Z.A., Jakhro, S.M.I. and Bugti, G.A. (2016) 'Comparative study on yield and yield components of psyllium (*Plantago ovata*) varieties in Balochistan', *Journal of Pharmacognosy and Phytochemistry*, 5(6), pp. 270–272.
- Ahirwar, S.K., Devi, A. and Agrawal, K.K. (2015) 'Impact of sowing date and fertility levels on growth parameters of isabgol', *Plant Archives*, 14(1), pp. 249–252.
- Akhtar, M., Herwig, B.K. and Faize, F.A. (2019) 'Depression and anxiety among international medical students in Germany: the predictive role of coping styles', *Journal of the Pakistan Medical Association*, 69(2), pp. 230–234.
- Arya, R.K., Kumar, P., Dahiya, G.S., Sutaliya, J.M., Kumar, R. and Chhabra, A.K. (2021) *Medicinal garden at a glance*. Hisar, India: CCS Haryana Agricultural University, MAP Section, Department of Genetics and Plant Breeding.
- Bafra, R.S., Upadhyay, A., Khan, N.A. and Dwivedi, S.K. (2011) 'Evaluation of different germplasms of isabgol for biochemical parameters, productivity and quantitative traits', *Journal of Applied Science Research*, 7, pp. 237–332.
- Brendan, O.N. (2024) *Agro-ecological zones of Pakistan*. Rome: Food and Agriculture Organization of the

- United Nations.
- Beniwal, B.R., Kumar, S.R. and Chaudhary, B.R. (2007) 'Phenotypic stability in isabgol', *Annals of Arid Zone*, 46, pp. 59–63.
- Dubey, R.B., Jain, S.K. and Maloo, S.R. (2009) 'Genetic divergence in isabgol (*Plantago ovata* Forsk.)', *Journal of Medicinal and Aromatic Plant Sciences*, 31(1), pp. 29–32.
- Deokar, G. (2016) 'Pharmaceutical benefits of *Plantago ovata* (isabgol seed): a review', *Pharmaceutical and Biological Evaluations*, 3(1), pp. 32–41.
- Gomez, K.A. and Gomez, A.A. (1984) *Statistical procedures for agricultural research*. 2nd edn. New York: John Wiley & Sons.
- Hendry, A. and Daulay, H.S. (1992) 'Relative performance of isabgol varieties', *Madras Agricultural Journal*, 79(10), pp. 585–587.
- Hazra, B., Biswas, S. and Mandal, N. (2008) 'Antioxidant and free radical scavenging activity of *Spondias pinnata*', *BMC Complementary and Alternative Medicine*, 8(1), pp. 1–10.
- Jour, T.Y., Baig, A.U.M., Burgess, P.J. and Fike, J.H. (2021) 'Agroforestry for healthy ecosystems: constraints, improvement strategies and extension in Pakistan', *Agroforestry Systems*, 95, pp. 1–15. <https://doi.org/10.1007/s10457-019-00467-4>
- Jadhav, S.P., Gadakh, S.R. and Aher, A.R. (2008) 'Evaluation of isabgol genotypes for quantitative and physiological traits', *Annals of Plant Physiology*, 22, pp. 149–152.
- Jain, S. and Paul, M.S. (2011) 'Genetic variability and character association analysis in isabgol (*Plantago ovata* Forsk.)', *Green Farming*, 2(1), pp. 15–19.
- Jat, R.S., Reddy, R.N., Bansal, R. and Manivel, P. (2015) *Good agricultural practices for isabgol*. Extension Bulletin. Anand, India: ICAR–Directorate of Medicinal and Aromatic Plants Research.
- Kalyanasundaram, N.K., Thanki, R.J., Talati, J.G., Amin, D.R. and Dalal, K.C. (1999) 'Estimation and variability of husk content in isabgol (*Plantago ovata* Forsk.)', Personal communication.
- Kang, M.S. (1993) 'Simultaneous selection for yield and stability in crop performance trials', *Agronomy Journal*, 85, pp. 754–757.
- Khan, K. et al. (2018) 'Effect of viscous soluble fiber on blood pressure: a systematic review and meta-analysis', *Nutrition, Metabolism and Cardiovascular Diseases*, 28(1), pp. 3–13.
- Kirti and Arya, R.K. (2019) 'Utilization of medicinal plants for food, feed and fodder for animals: a review', *Forage Research*, 45(1), pp. 23–27.
- Lockyer, S. and Nugent, A.P. (2017) 'Health effects of resistant starch', *Nutrition Bulletin*, 42(1), pp. 10–41.
- Ladjevardi, Z.S., Gharibahedi, S.M.T. and Mousavi, M. (2015) 'Development of a stable low-fat yogurt gel using psyllium husk gum', *Carbohydrate Polymers*, 125, pp. 272–280. <https://doi.org/10.1016/j.carbpol.2015.02.051>
- Nagaraju, K., Vishwanath, M. and Aruna, K. (2018) 'Seed quality enhancement techniques in medicinal and aromatic crops', *Journal of Pharmacognosy and Phytochemistry*, 7(3), pp. 104–109.
- Omidbaigi, R. and Mohebbi, M. (2012) 'Influence of sowing dates and nitrogen fertilizers on isabgol productivity', *Pakistan Journal of Biological Sciences*, 5(5), pp. 656–658.
- Patel, H.M. and Borad, P.K. (2016) 'Impact of sowing periods and methods on *Aphis gossypii* infestation in isabgol', *Journal of Medicinal and Aromatic Plant Sciences*, 27(2), pp. 262–264.
- Pakistan Forest Institute (PFI) (2018) *Herbal markets survey*. Peshawar: Pakistan Forest Institute.
- Pervez, Z.J., Ghulam, S. and Nazakat, U.K. (2010) 'Impact of climate change on wheat production in Pakistan', *The Pakistan Development Review*, 49(4), pp. 799–822.
- Rehana, S., Ghulam, S., Muhammad, N. and Hafiz, H.J. (2012) 'Impact of climate change on major agricultural crops in Punjab, Pakistan', *The Pakistan Development Review*, 51(4), pp. 261–276.
- Repsiene, R. (2001) 'Efficiency of placement fertilization for barley yield', in *Proceedings of the First World Congress on Conservation Agriculture*. Madrid, Spain, pp. 327–330.
- Rajesh, K., Vandana, A., Dahiya, G.S., Kumar, R., Sutaliya, J.M., Kumar, P. and Kumar, M. (2021) 'Seed yield performance of isabgol elite genotypes under semi-arid conditions', *Journal of Crop Breeding and Genetics*, 7(2), pp. 145–152.
- Reager, M.L., Deora, N.S., Tak, S.R. and Sanwal, R.C. (2017) 'Integrated weed management in isabgol under different sowing methods', *Annals of Agricultural Research (New Series)*, 38(2), pp. 218–225.
- Shah, A.R. (2020) 'Nutritional composition and health benefits of psyllium husk', *Nutrition Today*, 55(6), pp. 313–321.

- Sher, W.K. and Khatoon, S. (2018) 'Ethnobotanical studies of useful herbs of Gilgit valleys', *Pakistan Journal of Botany*, 40(1), pp. 43–58.
- Sharma, N.K. and Ratnoo, S.D. (2013) 'Isabgol yield enhancement through seed and fertilizer management', *Advanced Applied Research*, 5(2), pp. 112–114.
- Sharma, R. (2004) *Agro-techniques of medicinal plants*. New Delhi: Daya Publishing House.
- Sharma, A.K. and Garg, D.K. (2002) 'Correlation responses in isabgol', *Crop Improvement*, 29(1), pp. 110–112.
- Sangan, N.K., Ahlawat, T.R. and Dhindsa, K.S. (1992) 'Variability in quality traits of isabgol', *Indian Journal of Agricultural Research*, 26(2), pp. 81–86.
- Thanki, R.J. and Talati, J.G. (1983) 'Quality evaluation of isabgol seed', in *Proceedings of the V All India Workshop on Medicinal and Aromatic Plants*. Solan, India.
- Tyagi, S., Singh, O.P., Kumar, A., Sahay, S., Nanher, A.H. and Mishra, P.K. (2016) 'Performance of isabgol genotypes under Uttar Pradesh conditions', *Research in Environmental Life Sciences*, 9(10), pp. 1239–1241.
- Uzma, H., Shabib, H.S., Rafique, A. and Kauser, A.M. (2010) 'Economic impact of climate change on agriculture in Punjab', *The Pakistan Development Review*, 49(4), pp. 771–798.
- Zhang, J. et al. (2019) 'Isolation, structure and bioactivities of psyllium polysaccharides', *International Journal of Biological Macromolecules*, 139, pp. 409–420.