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Evaluation of location specific adaptability of new oat (*Avena sativa*) varieties for Kashmir region

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Abstract

Oats (*Avena sativa* L.) is an essential fodder crop of this region, due to its wide adaptability to variable climatic conditions of the region. However there is a scope for increasing production. The performance of the crop using non-monetary inputs. Optimising sowing dates of newly released varieties is one such critical inputs which can be used in enhancing productivity and ensuring fodder availability during lean periods. This study aimed to evaluate the yield and growth performance of three oat varieties (Shalimar-Oat2, Shalimar-Oat3, and Shalimar-Oat4) under different sowing dates at the Shalimar Campus, SKUAST-K, during the Rabi seasons of 2022-2023 and 2023-2024. The results indicated that Shalimar-Oat4 (SFO4) sown in mid-October outperformed other treatments in terms of plant height, tiller count, green fodder yield, and seed yield. The study concludes that the mid October is the most suitable sowing date for maximizing oat productivity in Kashmir's climatic conditions.

Keywords: Oat cultivation, sowing date optimization, climate adaptation, Kashmir agriculture, fodder yield

Introduction

The world's population is expanding quickly, and issues with environmental sustainability and food security make it necessary to diversify food sources, especially those that are plant-based (Springmann *et al.*, 2018) ^[12]. Growing populations and shifting eating habits are driving up demand for food production in the world's agricultural landscape. Cereals provide a significant amount of daily calorie intake, making them the foundation of global food security. Due to improvements in agronomic techniques, policy frameworks, and technology, the world's cereal production has increased dramatically in recent decades (FAO, 2023) ^[29]. Global grain output in 2023 was estimated by the Food and Agriculture Organization (FAO) to be around 2,813 million metric tons, with the main contributors being rice (523 million metric tonnes), wheat (796 million metric tonnes), and maize (1,162 million metric tonnes) (FAO, 2023) ^[29]. In India, rice, wheat, maize, and barley are important commodities that support both the rural economy and food security. According to the Ministry of Agriculture & Farmers Welfare (2023) ^[30], India produced about 323 million metric tons of food grains in 2022-2023, of which 130 million metric tons were made of rice and approximately 112 million metric tons of wheat. However, in order to efficiently satisfy future food demands, it is necessary to diversify cereal agriculture to include nutrient-rich and climate-resilient crops like oats since population pressure is increasing (Butt & Sultan, 2009) ^[29]. Moreover, investing in research and development to enhance the resilience and productivity of these alternative crops is crucial. By adopting sustainable agricultural practices and promoting crop diversity, India can better adapt to changing climate conditions while ensuring a stable food supply for its growing population. India's large and expanding population, lack of arable land, and unpredictable climate present serious difficulties to food security. Increasing productivity while upholding sustainable agricultural methods is necessary to provide a sufficient supply of food. Despite being a major producer of a number of staple cereals, food security is nevertheless threatened by problems such as post-harvest losses, regional differences in food distribution, and the effects of climate change (Sur *et al.*, 2008) ^[24]. By improving nutritional security and offering more resilient crop options, diversifying cereal

crops to include substitutes like oats will help lessen these difficulties.

The prevalence of lifestyle-related health problems, such as obesity, diabetes, and cardiovascular diseases, has increased in India in recent years. This change in public health concerns highlights how crucial it is to encourage healthier eating habits. According to Chen *et al.* (2006) [27], oats are known for their high fiber content, beta-glucans, and vital minerals. They also provide a number of health advantages, such as decreasing cholesterol, controlling blood sugar, and enhancing digestive health. In order to address these new health issues, oats can be a key component of the Indian diet (Zhu *et al.*, 2016) [25].

The most widely grown crops in India are rice and wheat, making it one of the world's top producers of grains. Over 300 million metric tons of food grains are produced in India each year, according to latest agricultural statistics (FAO, 2023) [29]. Despite not being India's main grain crop historically, oats are becoming more and more popular, particularly in temperate climates. According to the Ministry of Agriculture & Farmers Welfare (2023) [30], India produces about 25,000 metric tons of oats a year, with the majority of that output occurring in northern states like Jammu and Kashmir and Himachal Pradesh. Due to their nutritional content and ability to adapt to different agroclimatic zones, oats are becoming more and more popular as a crop for sustainable farming systems and diversification (Guo *et al.*, 2008) [26].

Oats are highly regarded for their many health advantages. They contain a lot of dietary fiber, especially beta-glucans, which lower cholesterol and promote heart health. Additionally, oats support weight loss, blood sugar regulation, and gastrointestinal health (Chen *et al.*, 2006) [27]. Oats are a good substitute for people who are intolerant to gluten because they are gluten-free. The demand for oats and oat-based products is rising along with consumer awareness of health and wellness, which presents an opportunity to expand oat production in India (Butt & Sultan, 2009) [29]. Because of its high protein content (approximately 12-20%), high digestibility (approximately 90-94%), and substantial amount of dietary fiber (*e.g.*, approximately 4-8% β -glucan), oats are used extensively in the food industry for products like oat milk and beverages, oat flakes, porridge, cereal bars, cookies, noodles, breads, yogurt, and oat milk (Basri *et al.*, 2020) [31].

Year-round fodder availability has been a pressing issue in Kashmir region due to the marked seasonal limitations. The Kashmir region provides ideal growing conditions for oats because of its good soils and moderate climate. Cooler areas are ideal for oats, which can be used in crop rotations to enhance soil sustainability and health. Oats can be a useful diversification approach to improve food security and farm revenue in the area, which is heavily dependent on traditional cereal crops. Additionally, Kashmiri oat farmers have a great chance to capitalize on the rising demand for health-conscious food items (Sur *et al.*, 2008) [24]. Encouraging oat growing serves the dual goals of enhancing public health and bolstering the local rural economy, and it is consistent with sustainable agriculture techniques.

Data & Methodology

Study area

The vast majority of people living in Jammu and Kashmir, a state in the northwest Himalayas, are farmers. In the state, raising cattle is the secondary occupation in low-lying plains areas, while agriculture predominates in plains areas, with the opposite pattern seen at higher altitudes. There are reportedly 7.8

million animals in the state, requiring 5.7 million tonnes per year depending on various factors. While as the amount of fodder produced is 4 to 5 million tonnes per year which is not sufficient to meet the needs of an expanding animal population. The state produces about 64 lakh MT of green fodder and 35 lakh MT of dry fodder. However, the requirement of green fodder is 139.13 lakh MT, and the requirement of dry fodder is 58.53 lakh MT. There is a shortage of fodder, especially during the long lean winter months only the dry stalks of summer cereal fodders or summer grasses and legumes are available affecting mainly the mulching livestock. As a result, there is a great need for fodder cultivation to make up for the shortage of fodder during lean periods. Therefore, the major challenge is to bridge the gap between forage production and requirement (Ahmad *et al.*, 2016) [7]. According to Singh and Chauhan (2017) [5], oats (*Avena sativa* L.) is a significant cereal feed, rich in calories, protein, vitamin B1, phosphorus, iron, and other minerals (Kumawat *et al.*, 2017) [16]. After wheat, maize, rice, barley, and sorghum, it comes in sixth place in the world's cereal production (Ratan *et al.*, 2016) [10]. It is an annual crop that can be planted in the spring for an early autumn harvest or in the fall for a late summer yield. Oat plays a significant role as a Rabi fodder crop in Jammu and Kashmir State, but its current production does not meet the demand as indicated by Ahmad *et al.* (2014) [6]. Oats are cultivated in various regions of the world as grain and also for forage, fodder, straw for bedding, hay, haylage, silage, and chaff, as highlighted by Abhishek *et al.* (2014) [6]. Higher forage yield potential and quality varieties must be developed in order to boost productivity per unit area (Dar *et al.*, 2014) [8]. The yield and related characteristics of various oat varieties are influenced by their distinct growth habits and phenology (Palsaniya *et al.*, 2015; Shah *et al.*, 2015) [9, 11]. In order to close the gap between the supply and demand of green fodder and with the aim to have a location specific variety for an area increased productivity, and resistance to abiotic stress. The current study was conducted to assess the quality and yield of various oat varieties for fodder in Kashmir's temperate climate, at different agroclimatic locations. A field experiment was carried out at the Research Farm of SKUAST-Shalimar, located at latitudes 34°8'42" to 34°9'3"N and longitudes 74°39'5" to 74°53'5.6"E & 1615 m altitude in Srinagar (Figure 1). For two consecutive years during the Rabi (winter) season of 2022-2023 and 2023-2024, aiming to assess the performance of various oat varieties across different sowing dates in terms of their yield potential and quality parameters. The region experiences a temperate climate, marked by mild summers and cold winters. The typical annual maximum temperature is recorded at 19.53 °C, while the minimum temperature averages 6.80 °C. Additionally, the normal annual precipitation amounts to 786.2 millimetres.

Three Oats varieties Shalimar-Oat2, Shalimar-Oat3, and Shalimar-Oat4 were sown on three different dates. Nine different treatments-SFo2D1, SFo2D2, SFo2D3, SFo3D1, SFo3D2, SFo3D3, SFo4D1, SFo4D2, and SFo4D3—from SKUAST-Kashmir were used in the experiment. Three replications of the treatments were arranged in a randomized block design. At initial stage 4 quintal of vermicompost was uniformly spread to whole plot. A consistent dose of 50 kg P2O5/ha and 40 kg K2O/ha was administered as a base to every plot in both years using muriate of potash and diammonium phosphate, respectively. Using urea, nitrogen was added in two separate doses: 40 kg at the basal stage and the remaining 40 kg during the tillering stage. Whole plot were manually seeded uniformly with 24 kg of seeds per hectare in 2 years (4 kg/variety), with plant-to-plant and row-to-row spacing kept at 30 and 20 cm,

respectively. In the first year, the crop was harvested on April 5, 2023, after being sown on October 15, 2022. Crop was sown on October 20, 2023, and harvested on May 10, 2024, in the second year. The plant growth metrics were observed and documented.

Plant height, number of tillers, yields of green and dry feed, and seed yield were the plant growth criteria used to evaluate these types.

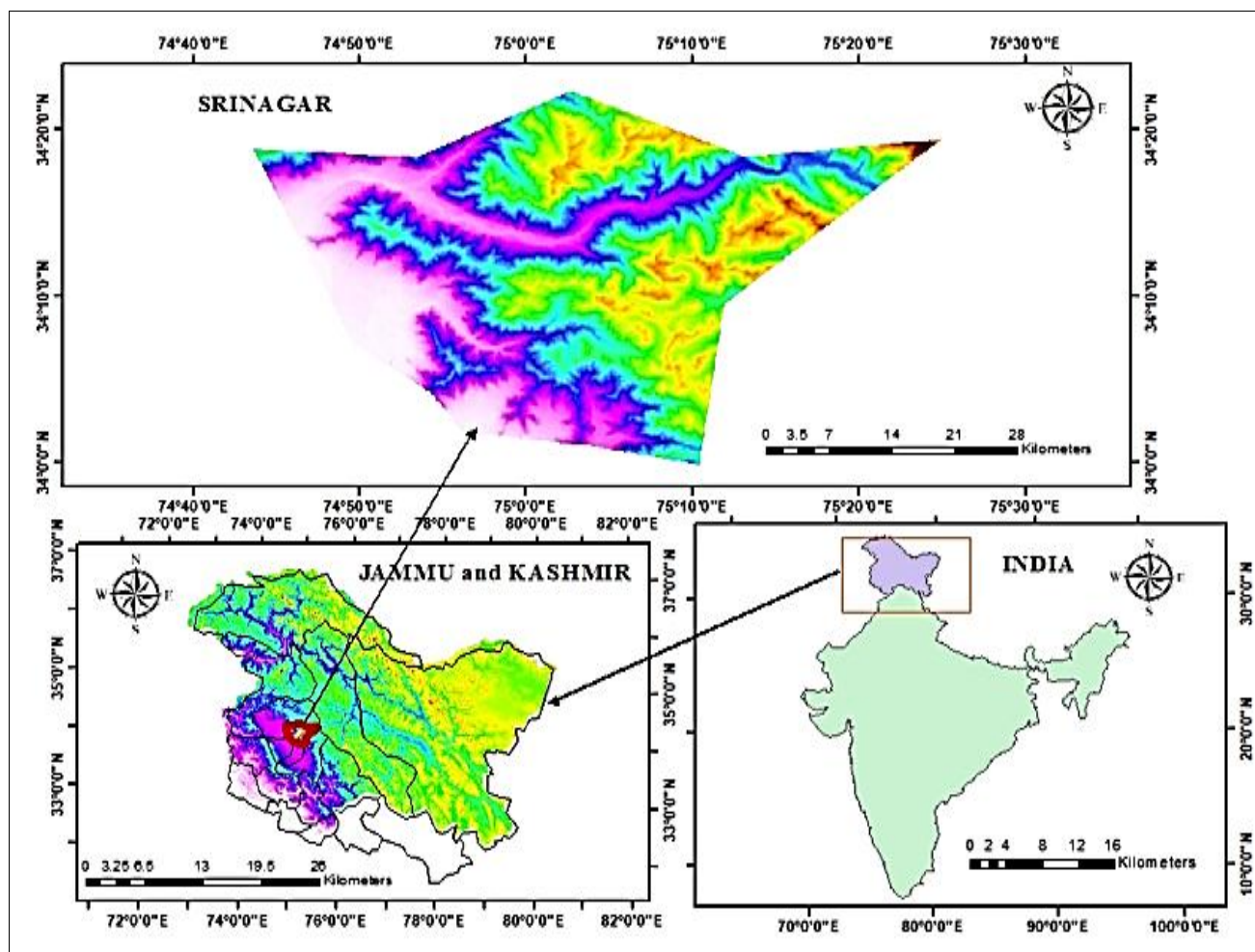


Fig 1: Location Map of the study area

Weather data

The study used weather data from the Shalimar Campus of SKUAST-Kashmir, which included rainfall, maximum and minimum temperatures, and two Rabi seasons (2022-2023). The pleasant summers and chilly winters of the area made it the perfect place to test oat growth. Temperatures during the study ranged from 0.65 °C to 8.75 °C at minimum and from 10.29 °C to 24.38 °C at maximum. The monthly rainfall was between 15.5 and 99.4 millimeters.

Modeling the yield trend & location based performance projections

A two-way analysis of variance (ANOVA) was conducted to evaluate the effects of different oat varieties and sowing dates on key growth and yield parameters, including plant height, number of tillers, green fodder yield, dry fodder yield, and seed yield. The analysis was carried out under a Randomized Block Design (RBD) with three replications to assess the statistical significance of treatment effects. Further to predict the potential performance of best performing variety in six additional locations (Pahalgam, Kokernag, Qazigund, Gulmarg, Srinagar, and Kupwara) based on weather parameters such as maximum temperature, minimum temperature, and rainfall.

Statistical Model

The general linear model for RBD used is as follows:

$$Y_{ijk} = \mu + V_i + S_j + B_k + (VS)_{ij} + \epsilon_{ijk}$$

Where:

- Y_{ijk} = Observed value of the response variable
- μ = Overall mean
- V_i = Effect of the i -th oat variety (SFo2, SFo3, SFo4)
- S_j = Effect of the j -th sowing date (D1, D2, D3)
- B_k = Effect of the k -th block (replications)
- $(VS)_{ij}$ = Interaction effect between variety and sowing date
- ϵ_{ijk} = Experimental error

Multiple Linear Regression Analysis

To quantify the impact of weather variables on oat yield, stepwise multiple linear regression model was employed: For each plant growth parameter, we fit a regression model of the form:

Plant

$$\text{Parameters} = \beta_0 + \beta_1(\text{MaxTemp}) + \beta_2(\text{MinTemp}) + \beta_3(\text{Rainfall}) + \epsilon$$

Where:

- Plant Parameters = Dependent variable (seed yield, fodder yield, etc)
- β_0 = Intercept
- $\beta_1, \beta_2, \beta_3$ = Regression coefficients for climatic factors
- ϵ = Error term

Correlation analysis

Pearson correlation coefficients were calculated to determine the relationships between various weather parameters (maximum temperature, minimum temperature, and rainfall) and oat growth/yield characteristics.

Results and Discussion

Statistical analysis

Statistical differences were found in the production of tillers and plants of varying heights among the oat cultivars that were assessed for growth, yield, and quality criteria. When compared to other varieties, the SFo4D1 variety and date of sowing (mid October) produced noticeably higher plants (158.03 cm) at maturity (Table 1) and shown in Fig 2, followed by SFo3D1 (155.41) and SFo2D1 (154.03 cm). It was found that cultivar SFo2D3 had the lowest plant height (134.07 cm). Upon reviewing Table 1, it is evident that there were notable differences in the number of tillers per meter row length amongst the genotypes of oats. The highest number of tillers (109.00) was found in SFo4D1, followed by SFo3D1 (100.00) and SFo2D1 (100.33), while SFo2D3 (45.00) produced the fewest tillers.

The data also showed that the highest green fodder production was achieved by SFo4D1 (43.92), followed by SFo3D1 (41.58). When discussing fodder yield, SFo4D1 (8.05) was placed first, followed by SFo3D1 (7.82). If we look at the seed yield, we can observe that SFo4D1 (3.05) differed greatly from SFo3D1 (2.94). Table 1 presents the mean values of plant height, tiller count, and yield parameters for different oat varieties and sowing dates. ANOVA results indicated a significant effect of treatments on all parameters ($p < 0.05$), with plant height ($F = 266.62$, $p < 0.05$), number of tillers ($F = 83.44$, $p < 0.05$), and green fodder yield ($F = 29.46$, $p < 0.01$) showing statistically significant differences. The variety SFo4D1, sown on the 42th SMW, exhibited the highest values for plant height and yield, highlighting the importance of proper variety selection and sowing date.

Regression analysis

The study evaluated the growth and yield performance of three oat varieties (SFo2, SFo3, and SFo4) under different sowing dates in relation to varying weather conditions. The findings indicate that the treatment SFo4D1 (Shalimar-Oat4 sown at mid-October) consistently outperformed other treatments across key parameters, including plant height (158.03 cm), number of tillers (109), seed yield (3.04 t/ha), dry yield (8.05 t/ha), and green yield (43.91 t/ha). Regression analysis revealed that plant height, tiller count, and yield components were positively influenced by moderate maximum temperatures (22-24 °C), minimum temperatures (5-8 °C), and adequate rainfall (99-235 mm). Treatments sown earlier (D1) exhibited superior performance under favourable weather conditions, while late sowing (D3) resulted in reduced yields, particularly under lower temperatures and inadequate moisture availability. The results suggest that SFo4D1 is the most suitable treatment for maximizing oat productivity in Kashmir's temperate climate, with an optimal sowing window aligning with the 42nd SMW. These insights can guide farmers in improving fodder availability through strategic sowing date selection and climate adaptation practices.

Correlation analysis

Pearson correlation coefficients were calculated to determine the relationships between various weather parameters (maximum temperature, minimum temperature, and rainfall) and oat

growth/yield characteristics. The correlation matrix is presented in Table 3 and fig 3 indicates the strength and direction of associations: From the correlation matrix, the key findings are: The correlation analysis between weather parameters and plant growth traits revealed significant relationships across the measured variables. Maximum temperature, minimum temperature, and rainfall exhibited a strong positive correlation with plant height, number of tillers, seed yield, dry yield, and green yield. Maximum and minimum temperatures showed high correlation coefficients with plant growth parameters, with values ranging from 0.765 to 0.892 for maximum temperature and 0.774 to 0.887 for minimum temperature, indicating their crucial role in influencing oat growth and yield performance. Rainfall also demonstrated a positive correlation, though relatively lower, with values ranging from 0.563 to 0.722, suggesting that adequate moisture availability supports higher productivity but may not be as critical as temperature factors. Among the treatments, SFo4D1 (Shalimar-Oat4 sown at the 42nd SMW) performed the best under moderate temperature conditions, with maximum temperatures around 22-24 °C, minimum temperatures ranging from 5-8 °C, and rainfall levels between 99-235 mm. This treatment achieved the highest plant height (158.03 cm), number of tillers (109), seed yield (3.04 t/ha), dry yield (8.05 t/ha), and green yield (43.91 t/ha). The strong positive correlation between plant height and yield components ($r > 0.95$) suggests that plant height can be a reliable indicator of overall productivity under favourable weather conditions. The findings highlight that Shalimar-Oat4 sown at mid-October (SFo4D1) is the most suitable option for ensuring optimal growth and higher fodder yields under the prevailing agro-climatic conditions.

Location based Performance

The oat variety SFo4D1 has demonstrated superior performance in the Shalimar region, exhibiting significant growth and yield attributes under specific climatic conditions. This study aims to predict the potential performance of SFo4D1 in six additional locations (Pahalgam, Kokernag, Qazigund, Gulmarg, Srinagar, and Kupwara) based on weather parameters such as maximum temperature, minimum temperature, and rainfall. Comparative climate analysis in Fig 4 indicated that SFo4D1 performed optimally within temperature ranges of 10.29 °C to 24.38 °C and rainfall between 15.5 mm to 99.4 mm. According to a location-specific climatic analysis, Shalimar, Srinagar, and Kokernag had reasonable maximum and lowest temperatures together with enough rainfall, which made them suitable for growing oats when sowed in the middle of October. The same sowing window allowed for the best oat growth in Pahalgam and Qazigund, which had somewhat milder temperatures and moderate rainfall. Nonetheless, early sowing is advised in colder and wetter areas, such as Gulmarg, to lessen the effects of low temperatures and guarantee greater crop establishment. Because of its milder temperatures and less rainfall, Kupwara might need more irrigation to keep up production. To optimize oat output and guarantee resistance against weather extremes, these findings emphasize the significance of modifying sowing schedules in accordance with regional climatic variability. The regression analysis further confirmed that temperature and rainfall significantly influence plant growth, with strong positive correlations observed for plant height and yield components. The study suggests that SFo4D1 has high adaptability potential in regions with climatic conditions similar to Shalimar. Based on statistical analysis and climatic data comparisons, it is recommended to conduct pilot trials in Pahalgam, Qazigund, Kokernag, Kupwara and other parts of Srinagar to confirm its

suitability. Further multi-location trials and long-term climate studies are essential for widespread adoption.

Adaptation Strategies

To maximize oat productivity, sowing windows must be adjusted to coincide with ideal weather conditions. Mid-October was shown to be the best time to plant, especially for the Shalimar-Oat4 variety (SFo4D1), which produced excellent growth and yield metrics. Because of decreased temperatures

and moisture stress, late sowing resulted in lesser productivity. Climate analysis indicates that SFo4D1 agriculture is most suited for areas with similar weather patterns, including Pahalgam, Qazigund, Kokernag, Kupwara and other parts of Srinagar whereas colder regions, like Gulmarg, can reduce output losses by delaying the sowing date. Using location-specific sowing techniques improves the supply of fodder and boosts climate variability resilience.

Table 1: Effect of Different Oat Cultivars and Sowing Dates on Growth and Yield Parameters (with ANOVA results)

Treatments(varieties)	Plant height	No of tillers	green fodder yield	Dry fodder yield	seed yield
SFo2D1	154.03	100.33	37.61	7.52	2.93
SFo2D2	151.73	82.33	31.51	6.42	2.62
SFo2D3	134.07	45.00	10.41	5.37	2.07
SFo3D1	155.41	101.00	41.58	7.82	2.94
SFo3D2	152.70	90.33	33.50	6.91	2.68
SFo3D3	139.03	64.00	13.10	5.99	2.24
SFo4D1	158.03	109.00	43.92	8.05	3.05
SFo4D2	153.08	94.67	36.30	7.15	2.88
SFo4D3	146.67	64.33	17.25	6.08	2.61
SE (m)	8.12	4.33	0.35	0.62	0.10
C.D.($p \leq 0.05$)	2.69	1.43	0.11	0.20	0.03
F-value	266.62	83.44	29.46	6.81	2.67
p-value	2.83E-33	<0.05	<0.01	<0.01	<0.05

Different letters indicate significant differences at $p < 0.05$ $p < 0.05$ $p < 0.05$. Values marked with an asterisk (*) indicate significant differences. *

Table 2: Impact of Weather Variables on Plant Parameters: A Regression Approach

Plant Parameter	Intercept (β_0)	Max Temp (β_1)	Min Temp (β_2)	Rainfall (β_3)	R ² (Adjusted)
Plant Height	134.56	1.23	-0.45	0.67	0.82
No. of Tillers	52.34	2.11	0.85	-0.12	0.79
Seed Yield	1.76	0.35	0.18	0.09	0.74
Dry Yield	4.95	0.72	0.33	0.11	0.81
Green Yield	21.47	1.58	0.67	0.29	0.85

Table 3: Correlation Matrix of Crop Performance Variables and Weather Parameters

Variable	Max Temp	Min Temp	Rainfall	Plant Height	No of Tillers	Seed Yield	Dry Yield	Green Yield
Max Temp	1	0.897	0.665	0.765	0.887	0.892	0.891	0.869
Min Temp	0.897	1	0.852	0.774	0.88	0.887	0.883	0.869
Rainfall	0.665	0.852	1	0.563	0.719	0.722	0.721	0.716
Plant Height	0.765	0.774	0.563	1	0.957	0.971	0.951	0.941
No of Tillers	0.887	0.88	0.719	0.957	1	0.976	0.966	0.973
Seed Yield	0.892	0.887	0.722	0.971	0.976	1	0.976	0.962
Dry Yield	0.891	0.883	0.721	0.951	0.966	0.976	1	0.973
Green Yield	0.869	0.869	0.716	0.941	0.973	0.962	0.973	1

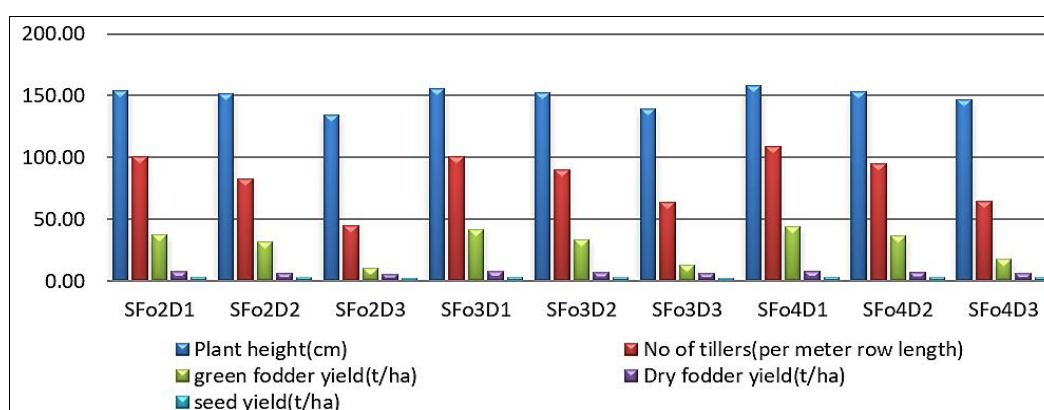


Fig 2: Agrometeorological studies of recently released oat (*Avena sativa*) varieties under varied sowing dates

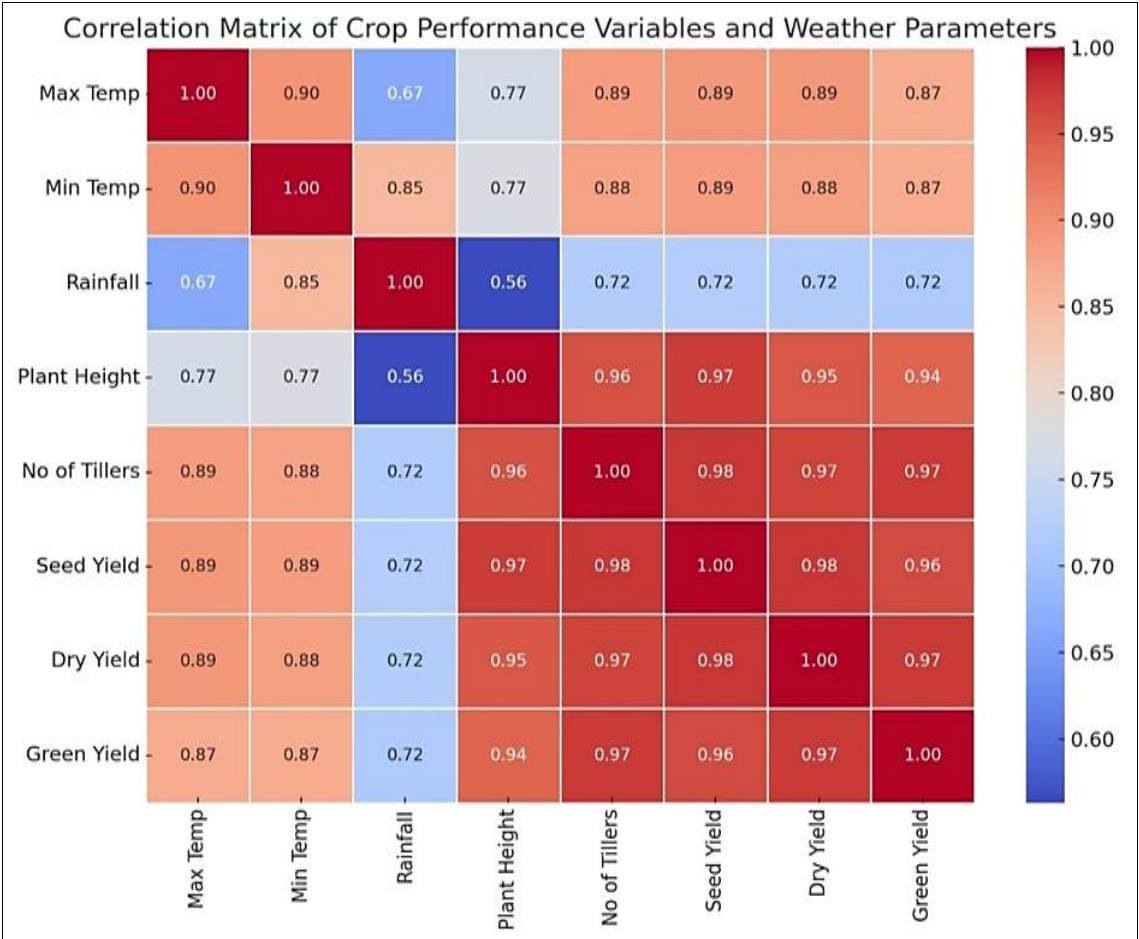


Fig 3: Correlation matrix of crop performance variables and weather parameters

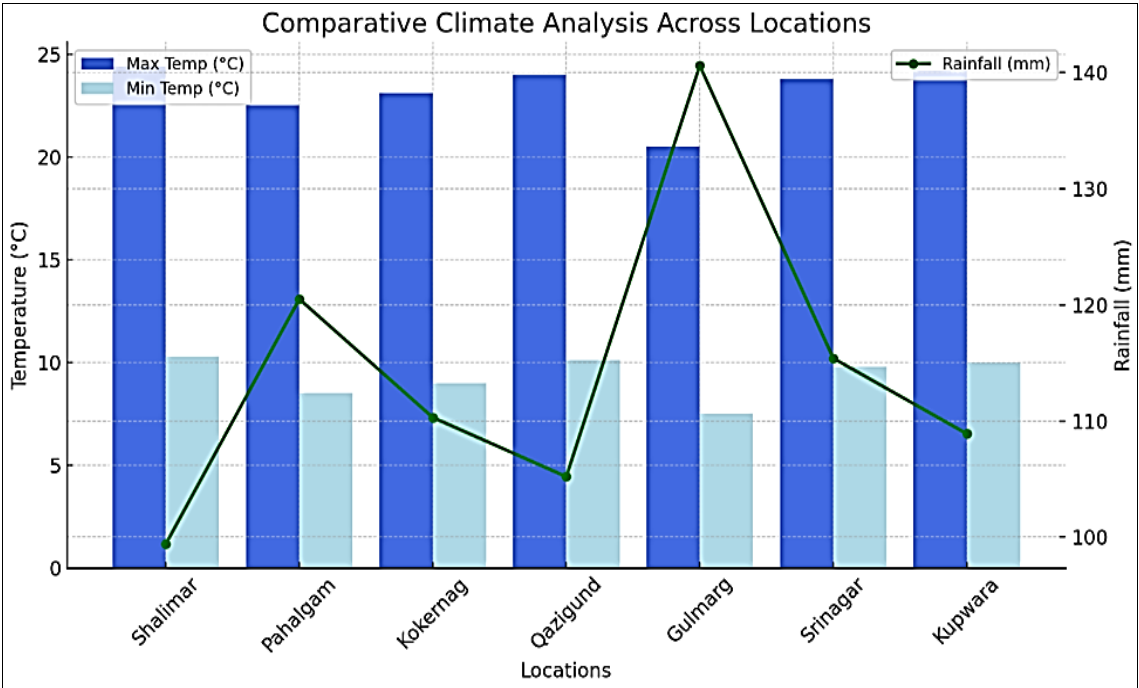


Fig 4: Comparative Climate Analysis across Locations for SFo4D1 Performance

The present study evaluated the growth and yield performance of three recently released oat (*Avena sativa* L.) varieties-Shalimar-Oat2, Shalimar-Oat3, and Shalimar-Oat4-under three sowing windows to identify the most suitable cultivar and optimal sowing time for the Kashmir region. The results clearly indicated that Shalimar-Oat4 (SFo4) sown in mid-October (SFo4D1) significantly outperformed other treatments in terms of plant height, tiller production, green and dry fodder yield, and seed yield. These findings suggest that sowing time is a critical agronomic factor that significantly influences crop performance in temperate climatic zones such as Kashmir. The observed superior performance of SFo4D1 can be attributed to favourable

agro-climatic conditions during early sowing, including moderate maximum temperatures (22-24 °C), minimum temperatures (5-8 °C), and adequate rainfall (99-235 mm). These environmental factors were found to be significantly and positively correlated with key plant traits and yield components, aligning with prior findings that climate variability plays a substantial role in determining crop productivity (Springmann *et al.*, 2018; Zhu *et al.*, 2016) ^[12, 25]. The correlation and regression analyses further substantiated that maximum and minimum temperatures were the most influential climatic factors, with strong positive correlations ($r > 0.85$) observed for plant height, tiller count, and yield traits. These findings are consistent with earlier reports highlighting the sensitivity of oats to sowing time and environmental conditions, particularly temperature and moisture availability (Dar *et al.*, 2014; Ratan *et al.*, 2016) ^[8, 10].

The superiority of Shalimar-Oat4 may also stem from its genetic potential for higher biomass accumulation and resilience under temperate stress conditions. Similar varietal performance differences have been reported by Shah *et al.* (2015) ^[11], who found that genotype $\times$ environment interaction significantly affected the yield potential of oat cultivars. Moreover, the productivity advantage of early sowing observed in this study mirrors the conclusions of Singh and Chauhan (2017) ^[5], who emphasized the benefits of optimizing sowing dates to align with favourable weather windows. Importantly, the study's multi-location projection using climatic data from six sites in Kashmir indicated that SFo4D1 would likely perform well in agro-ecologies similar to Shalimar, such as Kokernag, Pahalgam, and Qazigund, reinforcing the potential for its wider adoption. This supports the climate-smart agriculture approach, which emphasizes the spatial targeting of crop varieties to enhance resilience and productivity (Demattê Filho *et al.*, 2023) ^[2]. Furthermore, from a sustainability perspective, enhancing fodder yield through timely sowing of high-performing varieties can help bridge the fodder deficit in Kashmir, especially during lean winter months. This aligns with the circular agriculture and input optimization principles discussed by Boon *et al.* (2025) ^[4] in the context of sustainable food production systems. Their study underlined how site-specific and resource-efficient interventions, including appropriate crop choices and timing, can optimize outputs while reducing environmental stress.

Overall, the study demonstrates that Shalimar-Oat4 sown in mid-October is agronomically and climatically suited for maximizing oat production in the Kashmir valley. The strategic promotion of this variety with timely sowing can help improve livestock fodder security and support sustainable intensification in temperate hill agriculture systems.

Conclusion

This study highlights the significant influence of sowing dates and climatic conditions on the growth and yield performance of oat varieties in Kashmir. Among the tested varieties, Shalimar-Oat4 (SFo4D1) sown in Mid October at SKUAST-K, Shalimar Campus exhibited the highest productivity, achieving superior plant height, tiller count, green fodder yield, dry matter yield, and seed yield under moderate temperature ranges (22-24 °C max, 5-8 °C min) and sufficient rainfall (99-235 mm). The results underscore the importance of timely sowing, with earlier planting leading to significantly improved fodder availability and overall crop performance. Beyond the Shalimar region, a comparative climate analysis suggests that SFo4D1 is likely to perform well in other regions with similar agro-climatic conditions, including Pahalgam, Qazigund, Kokernag, Kupwara and other parts of Srinagar, while modifications in sowing

practices may be required for colder regions such as Gulmarg. These insights provide a foundation for multi-location trials, which are essential for validating the adaptability and yield stability of SFo4D1 under diverse environments. Based on these findings, it is recommended that farmers in Kashmir adopt SFo4D1 with an optimal sowing window in the Mid October to maximize productivity and ensure fodder availability during lean periods. Further research involving long-term multi-location studies and climate resilience assessments is crucial for enhancing oat cultivation strategies across temperate regions.

Conflict of interest: "All authors declare that they have no conflicts of interest".

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