



Available on <http://www.pjbt.org>  
 Pakistan Journal of Biotechnology  
 (PJB)  
 (P-ISSN: 1812-1837 and E-ISSN: 2312-7791)



## BARKAT: A NEW HIGH FODDER YIELDING OAT (*AVENA SATIVA* L.) VARIETY WITH BETTER NUTRITIONAL VALUE

Imtiaz Akram Khan Niazi<sup>1</sup>, Muhammad Aslam<sup>1</sup>, Muhammad Nadeem<sup>1</sup>, Muhammad Shakeel Hanif<sup>1</sup>, Sikandar Hayat<sup>1</sup>, Raees Ahmed<sup>2</sup>, Muhammad Jamil<sup>3</sup>, Abdul Basit<sup>1</sup>, Ahmad Hussain<sup>1</sup>, Ahmad Raza<sup>1</sup>, Ghulam Ahmad<sup>1</sup>, Aftab Ahmad Khan<sup>1</sup>, Muhammad Tanveer Ahmad Kalyar<sup>1</sup>, Suleman Raza<sup>1</sup>

<sup>1</sup>Fodder Research Institute, Sargodha, Punjab, Pakistan.

<sup>2</sup>Department of Plant Pathology, Faculty of Agriculture, University of Poonch Rawalakot, AJK, Pakistan.

<sup>3</sup>Department of Agronomy, University of Poonch Rawalakot, AJK, Pakistan.

E-mails: [raees@upr.edu.pk](mailto:raees@upr.edu.pk)

Article Received 20-04-2023, Article Revised 29-05-2023, Article Accepted 02-06-2023

### ABSTRACT

Oats are utilized primarily as feed for domestic animals and is also fourth most important cereal crop of the world. The Fodder Research Center, Sargodha, used conventional breeding techniques to generate the general cultivar "Barkat" of oat (*Avena sativa* L.). It will be launched in 2021. The "FRI-01" commercial cultivar is a highly uniform offspring of the crosses between parental accessions (No. 970 and No. 288) and subsequent selections in multiple segregating populations (F2 through F6) using pedigree procedures. The cultivar outperformed the commercial check "Sargodha-Oat 2011" by 10% and 12.76% in forage yield during 2014-2015 and 2015-2016 station trials, respectively, and by 13.32% in fodder yield during 2016-17 at the zonal level. It is a late-maturing green cultivar that produces light brown seed and has a tall, multi-tillering plant form. It gave 7.13% higher fodder yield during 2017-18 and 22.38% increase over check variety during 2018-19 in national trials. Forage qualities include high palatability (85%), protein content (10.6%), and tolerance to biotic and abiotic stresses. The flowers bloom roughly ten days after the reference variety. Barkat (FRI-01) sown on 1<sup>st</sup> October and 15<sup>th</sup> October gave highest fodder yield in comparison with other tested sowing dates while maximum green fodder yield 87 ton ha<sup>-1</sup> at 80 kg per ha seed rate and 30 cm row spacing. Barkat (FRI-01) will be extremely valuable cultivars in both irrigated and desert region of Punjab Province due to its high yield, great palatability, higher protein contents than standard check, and tolerance to biotic and abiotic stress. Also, the cultivar can serve as a parental line in future efforts to enhance oat genetics.

**KEY WORDS:** Oat, quality fodder, seed rate, spacing, sustainable yield, abiotic factors.

### INTRODUCTION

The cereal fodder crop oat (*Avena sativa* L.) is widely cultivated in Pakistan, both in irrigated and dry areas. Oats (*Avena sativa* L. and *Avena byzantina* Koch) rank fifth (Dost, 1997) in terms of world production of cereals. Oats account for more than 35 percent of the land under forages in Pakistan. The species may quickly multiply, and it has the potential to yield a delicious, nutritious, and popular fodder crop. It's resistant to environmental challenges and can thrive in a variety of conditions (Niazi *et al.*, 2020). It is often fed while still green, but it can also be fermented into silage or dried into hay for use during times of fodder scarcity. Animals seem to enjoy eating oat fodder because of its palatable texture and high nutritional value. Green fodder crops are usually harvested when they are about halfway through their flowering cycle, or later if

possible, so that the most possible yield of green fodder can be obtained with the least amount of quality loss. It also aids in the maintenance of body weights, the improvement of health, and the enhancement of milk yield in milking cattle, all of which would otherwise drop drastically during the winter fodder lean seasons (Favre *et al.*, 2019). Its straw is softer than wheat or barley and has more nutrients per serving. Equine, dairy, poultry, and young breeding animals all benefit from oats grain (Ahmad *et al.*, 2020). In the winter, when only dry kharif cereal fodder and dry summer grasses are available, farmers face a fodder shortage. Improved cultivars and agronomic approaches can boost fodder yield per acre by a factor of two to three (Gorash *et al.*, 2017). The dairy farming industry is currently experiencing a high demand for high yielding oats varieties. To that end, scientists at the

Fodder Research Institute in Sargodha bred a strain of oats called "Barkat" that is both incredibly nutritious and produces a lot of fodder. The purpose of this manuscript is to detail the qualities and practical applications of Barkat for widespread cultivation in the Punjab. The approved variety under consideration is good news for the feed crop industry. Potentially beneficial effects include increased income for fodder farmers and the dairy farming community as well as increased milk and meat production from livestock.

## MATERIAL AND METHODS

Barkat (FRI-01) was developed via pedigree selection of multiple segregating populations (F2-F6) resulting from a hybrid between parental accessions No.970 and No.288. Table 1 provides a snapshot of the number of cultivars in each generation and their respective stages of development. To increase the homozygosity in each generation, the spikes of certain plants were covered with Kraft paper bags to encourage self-pollination. At the F6 generation level, there was a great deal of homogeneity among the chosen offspring. Station and zonal trials were undertaken from 2014 to 2017, with quality assurance checks, and the results showed that the advanced breeding line with the code name "FRI-01" had superior qualities compared to the other progeny. Under adaptation yield studies, it was measured against the check variety "Sgd. Oats.2011" over multiple areas in the Punjab province in 2017-2019. The Deputy Director Federal Seed Certification

and Registration Department, Sargodha was provided with seed from the promising line "FRI-01" and the check variety "Sgd.Oats.2011" in order to carry out "DUS" trials in the growing seasons of 2019–20 and 2020–21. At National Uniform Fodder Yield Trials held across the country in 2017–18 and 2018–19, the promising line 'FRI-01' was put through its paces. Barkat, a new cultivar of oats, has been described. To determine the best timing to seed the promising line "FRI-01" for fodder production, trials were conducted at the Fodder Research Institute in Sargodha from 15 September 15 December, at 15-day intervals, during the crop years 2018-2019 and 2019-2020.

Throughout the 2018–19 and 2019–20, growing seasons, researchers observed how 'FRI-01' responded to varying concentrations of fertilizer, seed rates, and row distances. We were able to collect and compare data on a number of morphological, fodder yield, and quality parameters of FRI-01. Quality parameters comprised palatability, protein contents (%), and crude fiber (%), ash (%), crude fat (%) and NFE (%) while yield traits included green fodder yield (tons ha<sup>-1</sup>), plant height (cm), number of leaves per tiller, leaf length (cm), leaf width (cm), leaf color, number of tillers plant<sup>-1</sup>, and days to 50% blooming. Ca, Mg and zinc (%) were also studied

**Breeding History:** At the Fodder Research Institute in Sargodha, Pakistan, used the pedigree selection approach to create the promising line FRI-01 by crossing the native germplasm selections No.970 and No.288.

**Table 1: Advanced Breeding Lines “Fri-01” History and Pedigree Method.**

Year	Activity
2007-2008	No.970 X No.288
2008-09	The F1 generation was space-planted and mass-harvested to obtain sufficient seed for the F2 generation.
2009-10	The F2 generation was space-planted, and then 150 plants were chosen at random to have their seeds collected independently.
2010-11 2011-12	Each plant progeny were space-planted in a row for the F3 and F4 generation, and again the best plants were hand-picked.
2012-13	In the F5 generation, the best progeny were singled out by planting a small number of carefully chosen plants in a grid.
2013-14	In the F6 generation, we made the choice to adopt a uniform family.
2014-15, 2015-16	Testing of station output were carried out.
2016-17	Localization / Flexibility Test of Grass-Based Feeding Yield
2017-18	National trial of uniform green forage yield (1st Year)
2018-19	Trials of Nationwide Standard Green Fodder Yield Improvement Measures in Agronomy and Fertilizer Use
2019-20	1st DUS Testing and / Agronomic Trials/ Fertilizer Trials/ Pathology & Entomology trials
2020-21	2 <sup>nd</sup> DUS Testing/ Pathology & Entomology trials and Spot examination

## Species

Oats (*Avena Sativa L.*).

**Description of The Variety:** Botanical description of the line 'FRI-01' has been given in Annexure-1.

The Deputy Director of the Federal Seed Certification and Registration Agency in Sargodha was provided with seed from the promising line "FRI-01" and the check variety "Sgd.Oats.2011" in order to carry

out "DUS" trials in the coming growing seasons (2019–20 and 2020–21).

## RESULTS

**Fodder Yield Performance Trials:** The results of station testing, adaptation trials, and the National Uniform Fodder Yield Trials of the 'FRI-01' line are detailed below.

**Table 2: Station/ Regular Green Fodder Yield Trial (2014-15).**

Sr. No.	Name of Variety	Green Fodder Yield (t/ha)	Increase over Check
1	FRI-01	90.60	10.05 %
2	Sgd.oats.2011 (Check)	82.32	

Performance of FRI-01 in Station Yield Trial during the Year 2014-2015 at Fodder Research Institute Sargodha  
Green fodder production from the line 'FRI-01' was, on average, 10.05 percent higher than that from the check variety 'Sgd.Oats.2011'.

**Station/ Regular Green Fodder Yield Trial (2015-2016):**

**Table 3. Performance of FRI-01 in Station Yield Trial during the Year 2015-16 at Fodder Research Institute, Sargodha.**

Sr. No.	Name of Variety	Green Fodder Yield (t/ha)	Increase over Check
1	FRI-01	94.37	12.76 %
2	Sgd.oats.2011 (Check)	83.69	-

On an average, the line 'FRI-01' gave 12.76 % higher green fodder yield than the check variety 'Sgd.Oats.2011'

**Adaptation/ Zonal Green Fodder Yield Trial (2016-17):** In the course of the 2016–2017 Adaptation Yield Trials, the promising line 'FRI-01' was tested against

the control variety 'Sgd. Oats.2011' in a number of fields across the Punjab region. The outcomes are shown in the examples below.

Table 4. Performance of FRI-01 under Adaptation/ Zonal Green Fodder Yield Trial.

	Green Fodder Yield (t/ha)					Increase Over Check
	FRI, Sargodha	FRSS, Faisalabad	ARS, Bahawalpur	ESPU, Farooqabad	Average	
FRI-01	96.15	88.50	65.32	95.74	86.43	13.32 %
Sgd.oats.2011 (Check)	85.36	83.41	62.15	86.17	76.27	

The line 'FRI-01' averaged 13.32% more green yield than the control variety 'Sgd.Oats.2011' across four separate locations.

**National Uniform Fodder Yield Trials (2017-18 & 2018-19):** Throughout 2017-18 and 2018-19, the Coordinator of Fodder at NARC Islamabad conducted National Uniform Fodder Yield

Experiments at several areas using the promising line FRI-01. The production of green forage at the Punjab level is indicated in Tables 5 and 6.

**Table 5. Performance of Oats Line 'FRI-01' for Green Fodder Yield (t/ha) under National Uniform Fodder Yield Trial (NUFYT) during 2017-18.**

Entry	Average Green Fodder Yield (t/ha)				Increase over check
	AARI, Faisalabad	FRI, Sargodha	AZRI, Bahawalpur	AVG	
FRI-01	57.72	73.77	31.50	54.33	7.13 %
Sgd.Oat-2011 (Check)	56.17	65.43	30.53	50.71	

Green forage yield was 7.13 percentage points greater with Line FRI-01 compared to the check variety.

**Table 6. Performance of Oats Line 'FRI-01' for Green Fodder Yield (t/ha) under National Uniform Fodder Yield Trial (NUFYT) during 2018-19.**

Entry	Average Green Fodder Yield (t/ha)				Increase over check
	AARI, Faisalabad	FRI, Sargodha	Okara	Average	
FRI-01	100	154.32	45.67	99.99	22.38 %
Sgd.oats.2011 (Check)	90.74	116.05	38.33	81.70	

A higher yield of green fodder was produced by the Line FRI-01 than the check variety by a margin of 22.38%.

**Summary of Fodder Yield Trials**

**Table 7. Yield Performance Summary of Promising Line 'FRI-01' in Comparison with Check Variety 'Sgd.Oats.2011 in the Trials**

Sr. No.	Type of trials	Year	No of Trials	Ave. Green fodder yield (t/ha)		
				FRI-01	Sgd.Oats.2011 (check)	Increase over Check %
1.	Station Yield trials	2014-15 2015-16	2	92.48	83.00	11.40
2	Adaptability green fodder yield trials	2016-17	4	86.43	76.27	13.32
3	National Uniform Yield Trial	2017-18	3	54.33	50.71	7.13
4	National Uniform Yield Trial	2018-19	3	100	81.70	22.38

Parameters Studies: Characteristics that affect green fodder yield are compared between the 'FRI-01' line and the 'Sgd.Oats.2011' control variety in Table 7.

**Table 8. Comparison of Green Fodder Yield Related Parameters of Line 'FRI-01' with Check Variety 'Sgd.Oats.2011'.**

Characters	Advance Line FRI-01	Sgd.oats.2011 (Check)
Plant height (cm)	170	160
No. of leaves/ tiller	9-10	6-8
Leaf length (cm)	60- 65	50-55
Leaf width (cm)	2.5-3.0	2.0- 2.7
Leaf colour	Green	Green
No. of tillers/plant	12-15	10-13
Stem thickness (cm)	0.7- 0.9	0.6 - 0.8

According on the data in the table, the 'FRI-01' line outperforms the 'Sgd.Oats.2011' control variety in terms of plant height, number of leaves per plant, leaf length, leaf breadth, and number of tillers per plant.

#### Agronomic Studies

**Sowing Date Trials:** At the Fodder Research Institute in Sargodha, sowings of the promising line "FRI-01" were spaced by 15 days between September 15 and

December 15 during the crop years 2018–19 and 2019–20 to determine the best period for seeding. To see the findings, please refer to Table 9.

**Table 9. Effect of Date of Sowing on Green fodder Yield of "FRI-01".**

Sr. No.	Date of Sowing	Green Fodder Yield (t/ha)		Average
		2018-19	2019-20	
1.	15 <sup>th</sup> September	52.68	50.50	51.59
2.	1 <sup>st</sup> October	74.50	72.68	73.59
3.	15 <sup>th</sup> October	75.67	74.66	75.16
4.	1 <sup>st</sup> November	74.50	72.68	73.59
5.	15 <sup>th</sup> November	71.60	67.30	69.45
6.	1 <sup>st</sup> December	65.65	60.67	63.16
7.	15 <sup>th</sup> December	48.60	44.53	46.56

In comparison to other sowing dates, the promising line 'FRI-01' sown on the 1st and 15th of October provided the highest yield of green forage, as shown in Table 9.

**Seed Rate and Row Spacing Trials:** Between 2018-19 and 2019-20, the promising line 'FRI-01' was sown at various seeding rates and row spacings for optimal forage output. The average yield of green forage for both years is shown in Table 9.

(87 t/ha) at 80 kg/ha seed rate and 30 cm row spacing followed by 67 kg/ha seed rate and 30 cm row spacing which produced 84 t/ha green fodder.

The results (Table-10) revealed that the promising line 'FRI-01' produced maximum green fodder yield

**Table 10. Effect of different seed rates and row spacing on fodder yield (t/ha) of "FRI-01".**

Seed Rate (Kg/ha)	Row Spacing (cm)		
	Green Fodder Yield (t/ha)		
	15 (cm)	30 (cm)	45 (cm)
67	77	84	72
80	80	87	78
92	71	73	68

**Fertilizer Requirements:** Table 11 displays the results of a two-year study (2018–19 and 2019–20) of the

promising line 'FRI-01' and its response to varying doses of fertilizer. Table 11's data on green fodder yield shows that the promising line "FRI-01" responds best to

a dose of 114-84-62 NPK kg/ha, as it produced the most green fodder (75.19 t/ha) with this dose.

**Table 11. Effect of Different Fertilizer Levels on Green Fodder Yield of “FRI-01”.**

Sr.No.	Fertilizer Level (kg/ha)			Green Fodder Yield (t/ha)		Average
	N	P	K	2018 -19	2019 – 20	
1.	0	0	0	57.04	60.19	58.61
2.	102	76	56	65.37	69.81	67.59
3.	108	80	59	69.63	76.48	73.06
4.	114	84	62	70.56	79.81	75.19
5.	120	88	65	71.11	78.70	74.91
6	126	92	68	71.48	77.11	74.72

**Production Technology (Fodder):** To get the most fodder out of the promising line 'FRI-01,' it should be sown in the month of October. For the highest possible green fodder output at the lowest possible cost, we advise a seeding rate of 80 kg/ha, a row spacing of 30 cm, and a fertilizer application rate of 114 84 62 NPK Kg/ha.

**Optimum sowing Time: Month of October**

Seed rate: 80.0 kg/ha

Row Spacing: 30 cm

Fertilizer requirements: 114-84-62 N:P:K (kg/ha)

**Insect- Pests and Disease Reaction**

**Insect Pest Reaction:** The major insect of Oats is aphid. The average data regarding aphid infestation of FRI-01 for the (2019-20 and 2020-21) mentioned in Table-12.

**Table 12. Insect pest reaction.**

Sr. No.	Name of Variety	Infestation of Aphid per Tiller
1	FRI-01	4.90 %
2	Sgd.Oats.2011 (Check)	8.33%

Results show that line FRI-01 is more tolerant than check variety.

**Disease Infestation:** The line 'FRI-01' was evaluated against the major disease i.e. rust during the years 2019-20 and 2020-21 and their behavior is given in Table 13.

**Quality Analysis:** Dry matter, protein content, dietary fibre, and Ash were measured for both the promising line 'FRI-01' and the local check variety 'Sgd.Oats.2011 (Table-14).

**Table13 Response of FRI-01 along with check variety to Rust.**

S. No.	Name of Variety	Disease Response	
		2019-20	2020-2021
1.	FRI-01	MR	MR
2.	Sgd.Oats.2011 (Check)	MR	MR

(MR: Moderately resistant), The findings showed that the 'FRI-01' line has average rust resistance.

**Table-14 Proximate Analysis\*.**

Entry	Dry Matter (%)	Crude Protein	Crude Fibre	Ash	Crude	NFE
		(%)	(%)	(%)	Fat (%)	(%)
FRI-01	16.3	10.6	19.4	11.3	2.51	56.2
Sgd.oats.2011 (Check)	16.1	9.9	20.8	10.9	2.45	55.9

(\* Bio Chemistry Section, AARI, Faisalabad)

Crude protein, crude fat, and ash levels in the promising line "FRI-01" are all higher than in the check variety "Sgd.Oats.2011," demonstrating that this line has a higher nutrient value.

**Table 15. Minerals analysis.**

Name of Line	Ca(%)	Mg (%)	Zn (pp)
FRI-01	0.46	0.15	20.5
Sgd-Oats-2011	0.36	0.10	19.5

## Palatability Studies

**Table 16. Palatability**

	Palatability
FRI-01	85%
Sgd.Oats.2011 (check)	80%

The findings demonstrate that the promising Line "FRI-01" has superior flavor than the control variety.

### SUMMARY

The Fodder Research Institute in Sargodha, Pakistan, used the pedigree selection approach to generate the promising line "FRI-01" by crossing the indigenous germplasm selections No.970 and 288. After a series of choices, the F6 generation uniform line (designated as FRI-01) was chosen for further testing in station, adaptation, and national uniform fodder yield trials. The 'FRI-01' line was shown to be more productive than the 'Sgd.Oats.2011' control variety across all experiments.

### JUSTIFICATION

1. When compared to the control variety Sgd.oats.2011, it produces a higher yield of green fodder.
2. It has more plant height and more number of tillers than the check variety
3. It is better in nutritive value and palatability.
4. It is resistant to lodging.
5. It is tolerant to disease and insect/pest attack.

### Recommended Area for Cultivation

The proposed area of cultivation for candidate variety "FRI-01" is whole Punjab.

### DISCUSSIONS

Forage cultivar breeding aims to increase yields of forage crops while also enhancing their nutritional value (Rauf et al., 2016). Yet, in the present scenario brought about by global climate change, genotypes resistant in respect to drought as well as heat are required (Niazi et al., 2020). Compared to extreme temperature-sensitive varieties, heat-resistant types have the potential to remain green for longer and provide nourishment for a longer period of time (Niazi et al., 2015). Oat is a winter feed, although it can be stunted by repeated stress of water during the establishing or tillering period, and by extreme temperatures in duration of the last Developmental Period of Reproduction, reducing forage supply and quality (Niazi et al., 2020). It is possible that the cultivar's tillering capacity, plant height, and total leaf area will all decline as a result of abiotic stressors like drought and heat (Rauf et al., 2016). Quality of fodder effect milk and meat yields in animals. Infrequent amount of quality fodder is main cause of low output of milk and meat in animals (Patel and Patel, 2011). Different traits are reported to effect yield. (Hussain et al.

2010, Ahmed et al. 2014 and Nehvi et al. 2007)reported the positive effect of plant height, number of leaves/tiller, number of tillers/plant, and leaf area of green fodder yield. The results show that new oats variet "Barkat" was found tolerant to loose/covered smut, leaf spot and downy mildew diseases which are in agreement with Hussain et al. (2011). To provide continuous production in both irrigated and arid environments, a high-yielding cultivar was established using traditional pedigree selection. In comparison to the adaptive cultivar "Super Green Oats 2011," the cultivar that was generated, "Super Green Oats," shown greater resistance to the abiotic stress (Niazi et al., 2020). Breeders have also devised similar processes to construct climate-resilient types, which can produce progeny directly depending on a wide range of features and a host of environmental variables (Rauf et al. 2016).

Several quality parameters of forage cultivars are considered in order to determine which ones are most useful in promoting higher forage consumption and better animal health (Rauf et al. 2016; Gorash et al. 2017). Highly successful ability of forage is a strong indication of how much of it will be consumed over a given time period (Niazi et al. 2015). The developed cultivar far exceeded the commercial check variety in terms of taste. A greater amount of soluble sugar, a more succulent stem, and a higher leafiness all contribute to making feed more palatable (Rauf et al. 2016). In addition, it was shown that a protein boost improved the nutritional content of the leaves. There was a higher concentration of protein in "FRI-01" compared to commonly available controls. The "Barkat" cultivar we've developed has the potential to produce exceptionally nutritional and pleasant feed for animals, boosting their health and milk production, and will outyield existing cultivars under subtropical conditions.

### REFERENCES

- Ahmad, M., Jehangir, I. A., Rizvan, R., Dar, S. A., Iqbal, S., Wani, S. H., & Hassan, R. Phylogenetic Relationship of Oats (*Avena sativa* L): A Guide to Conservation and Utilisation of Genetic Resources. *Int. J. Curr. Microbiol. App. Sci.* **9**(11), 831-845. (2020).
- Ahmad, M., Dar, Z.A. and Mehfuza, H. A review on oat (*Avena sativa* L.) as a dual-purpose crop.

- Sci. Res. Essays, **9**(4): 52-59. (2014)  
<https://doi.org/10.5897/SRE2014.5820>.
- Dost, M. Fodder oats in Pakistan. Chapter VI. (1997).
- Favre, J. R., Albrecht, K. A., Gutierrez, L., & Picasso, V. D. Harvesting oat forage at late heading increases milk production per unit of area. *Crop, Forage & Turfgrass Management*, **5**(1), 1-8. (2019).
- Gorash, A., Armonienè, R., Mitchell Fetch, J., Liatukas, Ž., & Danytė, V. Aspects in oat breeding: nutrition quality, nakedness and disease resistance, challenges and perspectives. *Annals of Applied Biology*, **171**(3), 281-302(2017).
- Hussain, A., S. Khan, A. Bakhsh, M. Imran and M. Ansar. Variability in fodder production potential of exotic oats (*Avena sativa*) genotypes under irrigated conditions. *J. Agric. Res.*, **48**(1): 65-71. (2010)
- Hussain, A., Khan, S. Zahid, M., Shafiq, S. Safdar, S. and Ali, Z. A new high yielding oat variety for fodder in the rainfed potohar and irrigated areas of Pakistan. *Sci. Technol. Dev. (Pakistan)*. (2011)
- Nehvi, F.A., Wani, A. Shafiq, A. Hussain, M.I. Maqhdoomi, B.A. Allai, W. Yousuf and Z.A. Dar. Stability analysis for yield and yield related traits in fodder oats (*Avena sativa* L.). *Asian J. Plant Sci.*, **6**(4): 628-632. (2007).  
<https://doi.org/10.3923/ajps.2007.628.632>
- Niazi, I. A. K., Akhtar, S., Kohli, S., Naveed, A., Rauf, S., & Shehzad, M. Oat (*Avena sativa* L.) advanced lines outperform existing cultivars for forage yield and its components under terminal heat stress. *Pakistan Journal of Agricultural Sciences*, **57**(2). (2020).
- Niazi, I. A. K., Rauf, S., da Silva, J. A. T., & Munir, H.. Comparison of teosinte (*Zea mexicana* L.) and inter-subspecific hybrids (*Zea mays* L. × *Zea mexicana*) for high forage yield under two sowing regimes. *Crop and Pasture Science*, **66**(1), 49-61. (2015)
- Patel, K.V. and Patel, A.D. Extent of heterosis for green fodder yield and its components traits in sorghum [*Sorghum bicolor* (L.) Moench]. *Int. J. Plant Sci.*, **6**(2): 348-351. (2011)
- Rauf, S., Sienkiewicz-Paderewska, D., Malinowski, D. P., Hussain, M. M., Niazi, I. A. K., & Kausar, M. Forages: ecology, breeding objectives and procedures. In *Advances in Plant Breeding Strategies: Agronomic, Abiotic and Biotic Stress Traits* (pp. 149-201) (2016).. Springer, Cham.
- Rauf, S., Al-Khayri, J. M., Zaharieva, M., Monneveux, P., & Khalil, F. Breeding strategies to enhance drought tolerance in crops. In *Advances in plant breeding strategies: agronomic, abiotic and biotic stress traits* (pp. 397-445) (2016).. Springer, Cham.

---

Publisher's note: PJBT remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.



This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. To

view a copy of this license, visit <http://creativecommons.org/licenses/by/4.0/>

---