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PLANT BREEDING & GENETICS

DEVELOPMENT OF FAISALABAD OATS-21 (*AVENA SATIVA* L.): A NEW CLIMATE RESILIENT AND NUTRITIOUS OAT VARIETY

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ABSTRACT

Climate change and food security are emerging issues around the globe; not just for human being but also for the livestock sector. Lack of climate resilient fodder and scarcity of green fodder during the lean periods of the year are the biggest concerns for the farmers of the Punjab. In order to cope with these serious issues, Fodder Research Sub-Station, Ayub Agricultural Research Institute has developed a new climate resilient oat variety having More No. of tillers/ m², more crude protein than the existing cultivars and high fodder yield named as "Faisalabad oats-21" in Punjab, Pakistan. It performed best in a series of trials conducted at Fodder Research Sub-Station, AARI, Faisalabad and out-station yield trials throughout the Pakistan during 2007-2021. Candidate line was selected after screening of filial generation obtained by the cross of two germplasm lines i.e. PD2LV65 × AVON by following pedigree method of selection for better green fodder yield and disease resistance during 2007 and 2008. The candidate variety was tested in Preliminary yield trials (2015-16), Advance yield trials (2016-17), Zonal green fodder yield trials (2017-18) and National Uniform fodder Yield Trials (2018-19). It produced an overall 11.3% higher green fodder yield over check variety Sgd. Oats- 2011. It produced 18.2% and 16% higher green fodder yield than the check variety in Preliminary & Advanced yield trials, respectively. It consistently surpassed the check with 13.3 % higher green fodder yield in Zonal/Adaptability trials conducted at three different locations of Punjab. Faisalabad Oats-21 out yielded check variety in National Uniform Green Fodder Yield Trials by 5.4 % and 3.79% increase in green fodder in 2018- 19 and 2019- 20 respectively. It ranked 3rd in 2018- 19 and 2019- 20 in National/Adaptability trials. When the crop evaluated at different sowing dates, the crop sown on 15th November produced maximum average green fodder yield of 74.8 and 76.6 t/ha in 2019-20 and 2020-21 respectively. It had plant height about 132-135 cm. During the evaluation of its quality traits; it had good quantity of protein (7.42 %). Candidate line(F-411) along with check was supplied to FSC & RD during 2019-20 & 2020-21 to conduct "DUS" trials. Spot examination was conducted in 2021 in which Faisalabad Oats-21 was approved for general cultivation in Punjab. So, this variety could be a good option for the farmers as it is climate resilient and high yielding oat variety that is able to overcome the scarcity of fodder during lean periods of winter and unpredicted weather patterns.

KEYWORDS: *Avena sativa*; high yielding; climate resilient; disease resistance; lean period

INTRODUCTION

Avena sativa (Oats) is grown all around the world due to its nutritive profile. It belongs to the "Poaceae" family of crop plants (Boczkowska *et al.,* 2014). It is an allohexaploid crop of temperate region and its chromosome No. is 2n=6x=42. As a cereal crop after wheat, rice, maize, barley and sorghum, it stands at 6th position around the globe (FAOSTAT, 2021). *Oats* possess a good nutritional profile, palatable taste, better shelf-life and reasonably good stability. Oats

are recorded low in cost and do not cause any kind of allergy, so it is a major component of an infant's diet (Sterna *et al.,* 2016). We can also get unsaturated fatty acids and lipids from oats. Oat could be a good and potential oilseed crop as it contains valuable and high amount of lipids in its seed (Rana *et al.,* 2019).

Oat being a larger winter forage crop is grown as dual-purpose crop for chaff and silage. Its chaff is used for feed, pasture and forage straw. It is rapidly growing crop and when used as food, oat is a nutritious,

palatable and succulent crop (Al-Ajmi and AL-Refai, 2020). Oat possess therapeutic effects in heart diseases and exhibited the anti-cancer activities. In case of diabetes, it stabilizes the level of blood glucose and boost up the body's immunity (EFSA, 2014 and Menon *et al.,* 2016). Several bioactive phytochemicals in substantial amounts are present in oats. Most of these phytochemicals are antioxidants that include alpha-tocopherol, alpha-tocotrienol, saponins and avenanthramides etc. Much of the qualities of oats such as high dietary fibers (β-glucan) and antioxidant contents, enable this crop a valuable candidate to be utilized as food (Rasane *et al.,* 2015 and Sarantis *et al.,* 2021). Oatmeal is helpful to regulate insulin and blood glucose levels and to lessen down the LDL (Low-density lipoproteins) and cholesterol level in the body. People use oatmeal to cure moderate hypertension and to reduce the body weight as it enhances the gastrointestinal metabolism and activities. Its consumption in the food reduces the risk of diabetes and heart diseases (Li *et al.,* 2016).

If oats crop is cut at flowering stage or soon after it, many of its cultivars has shown an appreciable food value. So the need of swiftly increasing livestock population could be meet by these cultivars in Pakistan (Arabzai and Gul, 2021 and Sohail *et al.,* 2021). The crop variety that retains higher potential of yield along with general adaptation is considered as an ideal one (Niazi *et al.,* 2020). In Pakistan, under a wide range of soil and climatic conditions, forage oats are cultivated in winter. This is due to the fact that from mid-November to mid-January, farmers of this region faces an acute shortage of green fodder. To fulfill the fodder demands of livestock, farmers take oats as a valuable winter fodder. Most of the biomass of this crop is fed to animals when it stands green. The surplus material of the crop is stored as hay or farmers make silage from it that could be utilized during fodder scarcity periods. The green fodder of oats owns 30-35% dry matter and 10-13% proteins. In Pakistan, due to its health benefits, it is now considered for human consumption as well (Muhammad *et al.,* 2020).

Production of oats ranges from plain to hilly areas in Pakistan and that's why it is considered as a major winter and spring forage. In the country, from the total area of forage/fodder production, round about 35 % area is concealed by the oats. Under appropriate environmental circumstances, researchers got 2.4-3.2 t/ha seed yield (Govt. of Pakistan, 2020-21). Above twenty- three meters, seed yield is not very good. In plain areas of country like Punjab, in winter and spring season, oats fodder is valuable. During autumn, spring and early summer season, its demand got high in hilly areas. Oats give more yield in regard of dry matter and green biomass in mountainous areas.

Oats are soft and rich source of digestible raw proteins, total digestible nutrients, vitamins, fats and minerals like iron and phosphorus. In regard of this fact, in Pakistan, oat consumption is limited to the livestock feed (Sterna *et al.,* 2016) that's why it is grown in limited amounts. Researcher and agricultural scientists have also neglected this crop and a limited research work is present. In order to develop and evaluate the high yielding varieties of oats there is a calamitous need to enhance feedlots and to identify the better yielding oat varieties (Jamil *et al.,* 2019). The varieties with high food and feed values will further uplift the demand of the crop. Thus, development of an oat variety having abundant tillers, multi-cut nature, lofty crop growth, wide and extensive leaves and sophisticated nutritional value is the dire need of the hour.

An attempt has been performed in this respect, for the development of an oat superior variety i.e. "Faisalabad oats-21" an outcome of hybridization (PD2LV65 × Avon) followed by pedigree method of selection. This variety owns better and higher green fodder yield along with good nutritious profile. It has out yielded standard variety Sargodha Oats- 2011. In National Uniform Green Fodder Yield Trials, it gave better yield than check (Sargodha Oats- 2011) and stood third position during Rabi 2019- 20. The new strain possesses in built moderate resistance/tolerant against Alternaria leaf spot and Helminthosporium. It also exhibited tolerance to insect/pests and has high ratooning/re-sprouting tendency. In Pakistan, this variety will act as a nutritious Rabi fodder for animal feed.

MATERIALS AND METHODS

Location of the experiment

The experiment is carried out in the research area of Fodder Research Sub-Station, Faisalabad during 2007-2021 and also at multi-locations around the Pakistan. Geographical co- ordinates of Faisalabad are the rolling flat plains of north-east punjab. Its latitude is $31^0 25' 00''$ towards North and longitude is $73^0 04' 59''$ towards East, with an elevation of 186 meters above sea level. High evapotranspiration is reported in Faisalabad due to which its climate is arid or semi-arid. The recorded average yearly rainfall is almost 13.417mm, while average temperature during winter ranges from $21^0 C$-$28.6^0 C$ and in summer, average temperature rises between $30^0 C$-$45^0 C$. The humidity (average) is 35.17 g.m-3 (https://www.weather-atlas. com/en/pakistan/faisalabad-   climate#temperature) recorded on average yearly basis. The material and

Table 1. Detail of hybridization and selection during variety development process

Year	Filial generation / trial	Operation
2007-08	Crossing was done	F_0 seed was harvested
2008-09	F_1	Seed of F_1 cross harvested
2009-10	F_2	Single plant selection
2010-11	F_3	Single plant selection
2011-12	F_4	Single plant selection
2012-13	F_5	Single plant selection
2013-14	F_6	Progeny row selection
2014-15	F_7	Superior Progeny selected
2015-16	Preliminary Green Fodder Yield Trial	Yield Data Recorded
2016-17	Advance Green Fodder Yield Trial	"
2017-18	Zonal Green Fodder Yield Trial	"
2018-19	National Uniform Green Fodder Yield Trial	"
2019-20	National Uniform Green Fodder Yield Trial,1st DUS Testing/ Agronomic Trials	Data recorded for National trial and Agronomic studies and DUS studies were conducted by FSC&RD
2020-21	2nd DUS Testing/ Agronomic Trials	Data recorded for Agronomic studies and DUS studies were conducted by FSC&RD

methodology adopted for the collection of various types of biological data from the experiments conducted are given as under.

Collection and evaluation of germplasm

Oat candidate line "Faisalabad Oats-21" was developed at Fodder Research Sub-Station, Faisalabad via hybridization / pedigree method of selection. Candidate line was selected after screening of pedigree obtained by the cross of two germplasm lines i.e. PD2LV65 × AVON for better green fodder yield and disease resistance during 2007 and 2008. The key characteristics of Parental Lines of the candidate line Faisalabad oat-21are given in the **Fig. 1.** During 2008-2009, seed from the pedigree i.e. C.081-12-6-3-9-18-411 was harvested. The candidate line was subjected to single plant selection during 2009 to 2013. During 2013-14, progeny rows were selected on the basis of mean performance. During 2014-15, superior progeny was selected. The screening was done on the basis of more tillering, more plant height, better rationing ability, disease resistance and most importantly for high green fodder yield.

The candidate variety was evaluated in preliminary green fodder yield trials and yield data was recorded during 2015-2016. During 2016-17, the test line was evaluated in advance / station yield trials. The candidate line was studied during 2017-18 in zonal green fodder yield trials. During 2018-19 and 2019-20, the candidate line was evaluated in National Uniform Fodder Yield Trials (NUFYT) conducted at different locations throughout the country. Subsequent factors of Faisalabad Oat were studied at Fodder Research Sub-Station, Ayub Agricultural Research Institute, Faisalabad. Sgd. Oats-2011 was used as check variety. All the factors were reconfirmed during 2019-20 and 2020-21 by the FSC&RD (Federal seed certification and Registration department), Islamabad in DUS test. In all yield trials, RCBD (randomized complete block design) was followed by 3 replications with plot size (1.8m×5). Details of Hybridization and Selection during Variety Development Process of oat is given in **Table 1.**

Data recording

Morphological characterization

Data was recorded for different green fodder yield related morphological characters like plant height, number of leaves, leaf area, stem thickness, leaf color
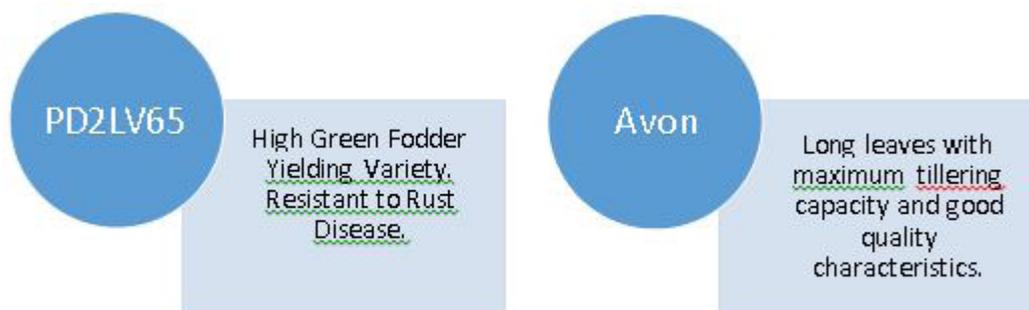

Fig 1. Key Characteristics of Parental Lines of the candidate line Faisalabad Oat-21

and days to 50% flowering of Faisalabad oats and check (Sgd. Oats-2011). Plant height of ten plants from each replication (average of ten plants) at maturity stage was measured with the help of meter rod in centimeters. No. of leaves of ten plants / replication were counted manually. Leaf area (cm$^{2)}$ was measured by recording the length at 3 positions of the leaves and calculating their average value. That average leaf length was multiplied with leaf width in centimeters. In that way, leaf area of ten plants / replication was recorded. Average Stem thickness was measured in inches with the help of Vernier caliper from 3 positions on stem. Ultimately, stem thickness of ten selected plants / replication was recorded. Data regarding days to 50% flowering was counted from the date of sowing till the 50% heads emerged from the panicle.

Agronomic parameters

Data regarding agronomic parameters like date of sowing, fertilizer level, seed rate and row spacing trials was also documented. Proposed line Faisalabad Oat and check were sown at 5 different sowing dates 15 October to 15 December for 15 days interval during 2019-20 and 2020- 21 at Fodder Research Sub-Station, AARI, Faisalabad. Newly developed strain Faisalabad oat as well as check cultivar was tested at 5 different doses of nitrogen, phosphorous and Potassium during 2019-20 and 2020-21. The NPK doses in kg/ha were; T1 (100-74-54), T2 (107-79-58), T3 (114-84-62), T4 (121-89-66) and T5 (128-94-70) respectively.
The promising line Faisalabad Oats-21 was sown at 3 different seed rates i.e. 60t/ha, 75t/ha, 100t/ha respectively by broadcast method to find best seed rate. The promising line Faisalabad oat- 21 was also sown at 3 different row spaces i.e. 15cm, 30cm, 45cm respectively to find the best suited row space for the crop.

Plant pathological and entomological studies

The variety Faisalabad Oats-21 along with check variety Sgd. Oats- 2011 were screened under artificial inoculations for the disease i.e. leaf rust of oats with the collaboration of plant pathology section of Ayub Agricultural Research Institute, Faisalabad. Insect attack was also counted against chewing / sucking insects with the help of Entomological section of Ayub Agricultural Research Institute, Faisalabad.

Biochemical analysis

Proximate analysis of Faisalabad Oats-21 along with check variety Sgd. Oats- was done for crude protein, crude fiber, crude fat, ash and dry matter by Bio-chemistry section, Ayub Agricultural Research Institute,

Faisalabad by following the recommendations given by AOAC in 1990 and AOCS in 1997.

Average digestibility coefficient

The Average Digestibility Coefficient of Faisalabad Oats-21 was calculated by the Livestock Production Research Institute, Okara.

Palatability analysis

The palatability analysis of Faisalabad Oats-21 was performed by the Agronomist Forage Production, Ayub Agriculture Research Institute, Faisalabad.

Statistical analysis

Data of all the recorded traits was subjected to analysis of variance (Steel *et al.,* 1997) and mean comparison test (Tukey, 1949) throughout the growth period to find out the genetic variations among the recoded traits. All morphological traits depicted the significant variation for yield.

RESULTS AND DISCUSSION

Yield performance of advance line F-411 in different yield trials

Oats advance line F- 411 is a multicut, high green fodder yielding genotype with good grain yield. It is moderately resistant to leaf rust of oats. Resistant to sucking/ chewing insects. Its yield performance remained very good throughout the evaluation studies. The new strain F- 411 produced 18.2% and 16% higher green fodder yield than the check variety in Preliminary & Advanced yield trials respectively, conducted at Fodder Research Sub-Station, Ayub Agricultural Research Institute, Faisalabad. It consistently surpassed the check with 13.3 % higher green fodder yield in Zonal/Adaptability trials conducted at three different locations of Punjab. The purposed variety Faisalabad Oats-21 out yielded check variety in National Uniform Green Fodder Yield Trials by 5.4 % and 3.79% increase in green fodder in 2018- 19 and 2019- 20 respectively. It ranked 3rd in 2018- 19 and 2019- 20 in National/Adaptability trials. Its green fodder yield potential i.e. 179.32 t/ha achieved in 2019-20 at ESPU, Farooqabad. On over all bases, in all the trials, it produced 11.34 % higher green fodder yield than check variety. Our findings are in accordance with those of Muhammad *et al.,* 2020 and Niazi *et al.,* 2020. Details of yield performance is given in **Fig. 2.**

Agronomic studies

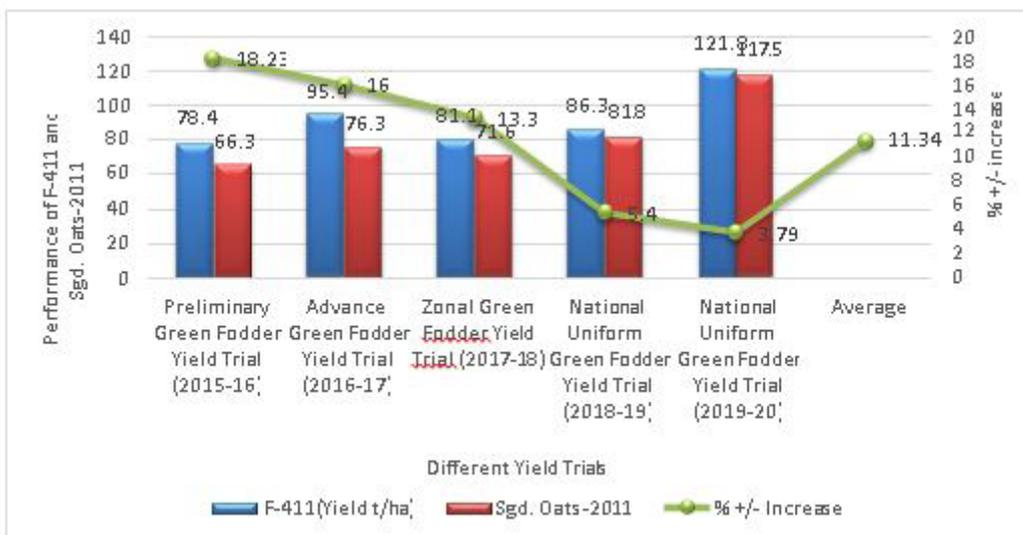Following studies were carried out at Fodder Research Sub-Station, Ayub Agricultural Research Institute,

Fig. 2. Yield performance of Oats Advance Line F-411 in different yield trials

Faisalabad in collaboration with Agronomy Research Institute, Ayub Agricultural Research Institute, Faisalabad.

Planting date trials
Planting date studies and fertilizer trials were conducted at Fodder Research Sub-Station, Ayub Agricultural Research Institute, Faisalabad during 2019-20 and 2020-21 to fix specific agronomic requirements of the candidate variety Faisalabad Oats -21. The results of planting dates trials during 2019-20 and 2020-21 are demonstrated in figures 3 and 4 respectively. The results revealed that the promising line 'F-411' sown on 1st to 15th November gave maximum green fodder yield in comparison with other sowing dates. However for multiple cuttings it may be sown during the month of October. Al-Ajmi and Al-Refai (2020) reported the same findings while working on *Avena sativa* L.

Fertilizer requirements
The response of promising line 'F-411' to different fertilizer doses was studied during the years 2019-20 and 2020-21. The results of trials of different fertilizer doses given to the crop during 2019-20 and 2020-21 are given in Fig. 5. Results revealed that the promising line 'F-411' is more responsive to fertilizer dose of 114-84-62 NPK kg/ha as it produced maximum green fodder yield of 70.4 t/ha. Our findings are in accordance with those of Verna *et al.,* 2016 and Niazi *et al.,* 2020.

Seed rate and row spacing trials
The promising line 'F- 411 was sown at Agronomy Forage Production, Ayub Agricultural Research Institute, Faisalabad at different seed rates and row

spacing for maximum green fodder yield during the year 2019-20 and 2020-21. Average green fodder yield of both years is given in figure 6. The results revealed that the promising line 'F- 411 produced maximum green fodder yield of 129 and 140 t/ha at seed rate of 75kg and 30 cm row spacing during both the studied years (2019-20 and 2020-21) respectively. Our findings are in accordance with those of Verna *et al.,* 2016 and Muhammad *et al.,* 2020.

Diseases and insect pests reaction

Alternaria leaf spot and *helminthosporium*
The screening study was conducted by Chief Scientist, Plant Pathology Research Institute, Ayub Agricultural Research Institute, Faisalabad against Alternaria leaf spot and Helminthosporium leaf spot and it was carried out at Fodder Research Sub Station, Ayub Agricultural Research Institute, Faisalabad during 2020-21. The candidate line F- 411 and check variety Sgd. Oats-2011 was placed in moderate resistant (R) group as mentioned in table 2. Our findings are in accordance with those of Da Silva *et al.,* 2012.

Insect pests studies
Chief Scientist, Entomological Research Institute, Ayub Agricultural Research Institute, Faisalabad conducted the said investigation at Fodder Research Sub Station, Ayub Agricultural Research Institute, Faisalabad, against sucking insects during 2020-21. The data collected is presented in **Table 2.** Our findings are in accordance with those of Maneva *et al.,* 2008; Vasilina *et al.,* 2009 and Kumar *et al.,* 2017.
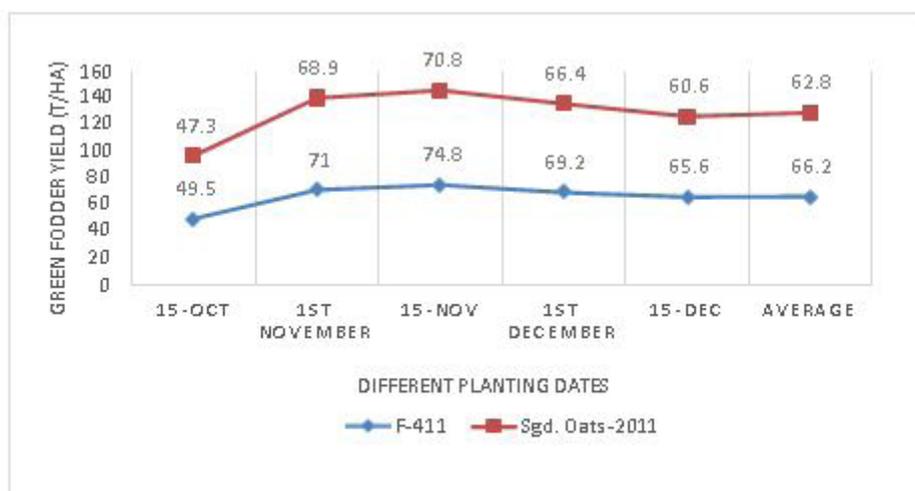
Fig. 3. Planting Date Trial of Oats Advance Line F- 411 (2019-20) (Green fodder yield (t/ha))

Fig. 4. Planting Date Trial of Oats Advance Line F- 411 (2020-21) (Green fodder yield (t/ha))

Figure 5. Fertilizer Trial of Oats Advance Line F- 4-11 (2019-20 & 2020-21) (Green fodder yield (Kg/ha))
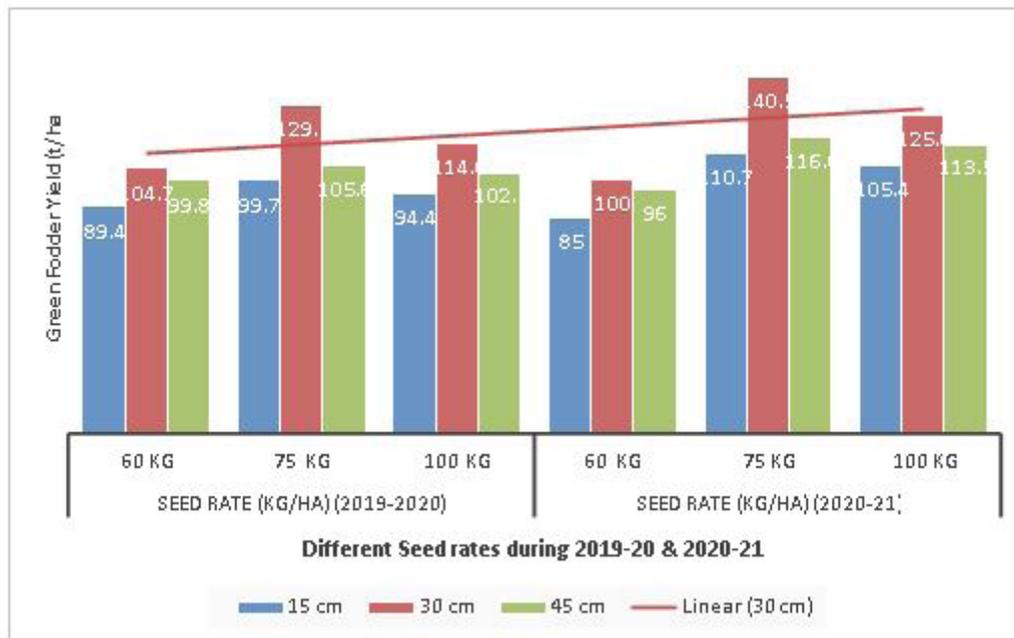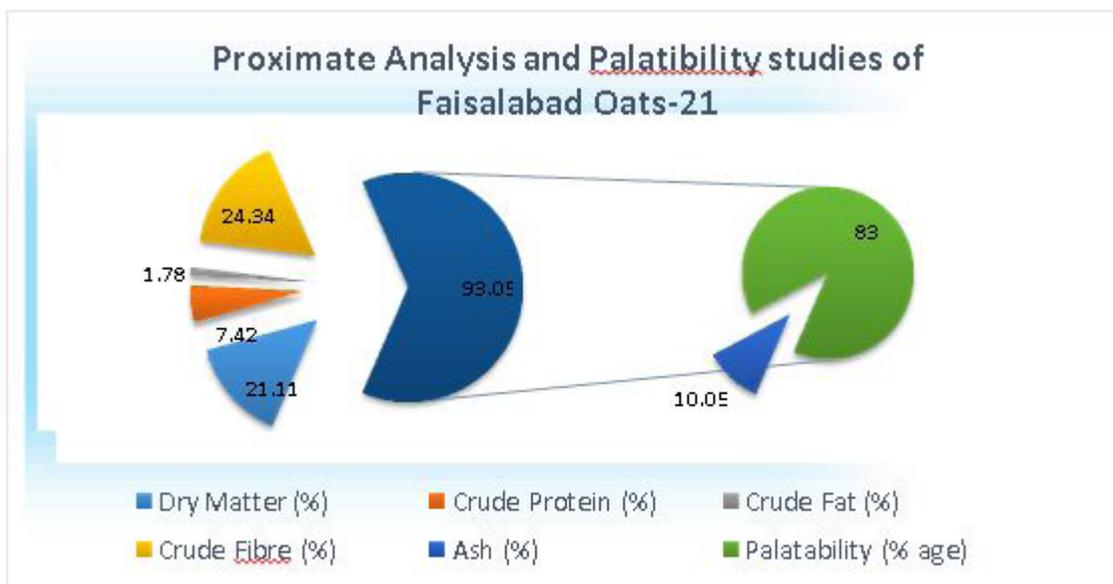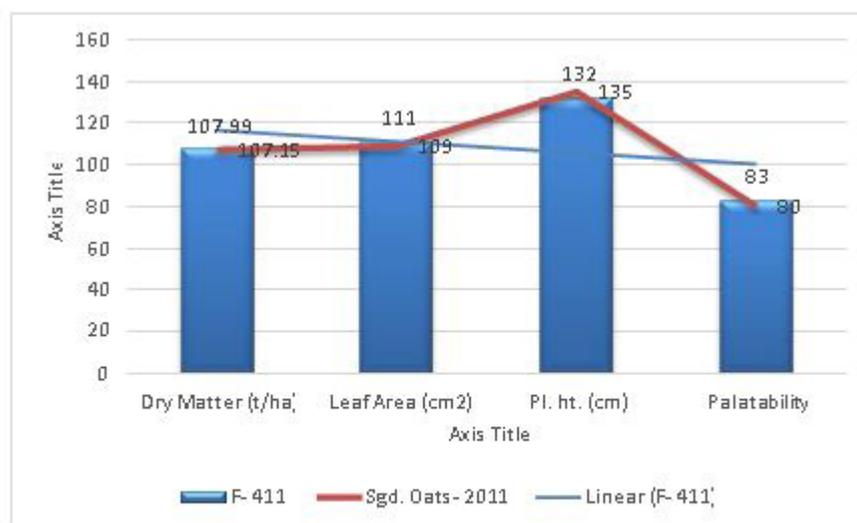

Figure 6. Effect of Different Seed Rates and Row Spacing on Green Fodder Yield of F-411 (2019-20 & 2020-21) (Green fodder yield (t/ha))

Biochemistry section, Ayub Agricultural Research Institute, Faisalabad

Fig. 7. Proximate Analysis and Palatability studies of Faisalabad Oats-21 (2019-2020)

Pakistan Agricultural Research Council, Islamabad

Fig. 8. Comparison of dry matter, palatability % and other morphological parameters of F-411 and Sgd. Oats-2011 (2019-2020)

Table 2. Response of F-411 and check towards the insect pest attack (Green fodder yield inKg/ha)

S. No.	Line/variety	Aphid	Avg. green fodder yield (kg/ha)
1.	F- 411	4.20a	2560
2.	Sgd. Oats- 2011	4.80a	2458

Quality characteristics

This new candidate line is suitable for milch/ruminant animals. It possesses the various quality parameters give in **Fig. 7.** It possess 21.11 % dry matter, 7.42 % crude protein, 1.78 % crude fat, 24.34 % crude fiber and 10.05% ash as analyzed and reported by the Biochemistry section of Ayub Agricultural Research Institute, Faisalabad. Our findings are in accordance with those of Rasane *et al.,* 2015. Faisalabad Oats-21 has shown a significant percentage of palatability i.e. 83% while the palatability of check variety i.e. Sgd. Oats-2011 was 80 %. Comparison of dry matter, palatability and other morphological parameters of F-411 and Sgd. Oats-2011 was analyzed and reported by Pakistan Agricultural Research Council, Islamabad in 2019-2020. Our findings are in accordance with those of Niazi *et al.,* 2020. This comparison is represented in **Fig.7 and 8.**

CONCLUSION

Rapid increase in human population put direct encumbrance on food supply chain. Livestock is a primary source of healthy food for human being. So there is a dire need to boost the livestock production in the country. Good quality fodder production may fill up the supply and demand gap of livestock feed requirements. Oats as nutrient rich fodder could be a good source in this regard. Oats (Avena sativa L.) is among the major winter fodder crop in Punjab, Pakistan. It is concluded from the present study that new strain of oats F- 411 is an outcome of hybridization (PD2LV65 × Avon) followed by pedigree method of selection. This new genotype was evaluatedfor its genetic potential regarding fodder production throughout the fodder growing areas of Punjab. Its maximum green fodder yield potential i.e. 179 t/ha was achieved at Experimental SeedProduction Unit, Farooqabad in National Uniform Green Fodder yield trials (Rabi 2019-20). The new strain possesses in built moderate resistance/tolerant against Alternaria leaf spot and Helminthosporium. It also exhibited tolerance to insect/pests. This is a multicut advance line, with high ratooning/re-sprouting tendency. It is a dual purpose (fodder and grain), nutritious and multicut oats advance line with higher forage tonnage. It is long heighted variety having broad leaves, more number of tillers and good palatability. Its re-sprouting tendency/
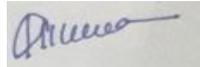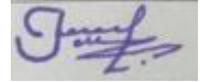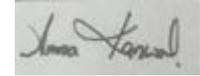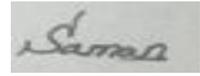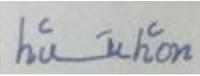
capacity is very high. The new strain is suitable for cultivation in all areas of Punjab province.

REFERENCES

Al-Ajmi, M.H. and S.I. AL-Refai. 2020. Effect of early planting dates on the growth and yield of two varieties of oat (*Avena sativa* L.). Plant. Arch. 20:124–127.

AOCS, 1997. Physical and chemical characteristics of oils, fats and waxes, in: official methods and recommended practices of the American Oil Chemists' Society, AOCS Press, Champaign, Illinois.

Arabzai, M.G. and H. Gul. 2021. Application Techniques of Molecular Marker and Achievement of Marker Assisted Selection (MAS) in Three Major Crops Rice, Wheat and Maize. Int. J. Res. Appl. Sci. Biotechnol. 8:82–93.

Boczkowska, M., J. Nowosielski, D. Nowosielska and W. Podyma. 2014. Assessing genetic diversity in 23 early Polish oat cultivars based on molecular and morphological studies. Genet. Resour. Crop. Evol. 6:927–941.

Da Silva, M.R., J.A. Martinelli, L.C. Federizzi, M.S. Chaves and M.T. Pacheco. 2012. Lesion size as a criterion for screening oat genotypes for resistance to leaf spot. Europ. J. Plant Pathology, 134(2):315-327.

EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA). 2014. Scientific Opinion on the evaluation of allergenic foods and food ingredients for labelling purposes. EFSA J. 12:3894.

Food and Agriculture Organization Corporate Statistical Database. 2021. New food balances. FAOSTAT. Available via FAO.

Govt. of Pakistan, 2020-21. Pakistan Economic Survey, Ministry of Finance, Economic Advisor's Wing, Islamabad.https://www.weather-atlas.com/en/pakistan/faisalabad-climate#temperature.

Jamil, S., Arshad, S., Kanwal, S., Razzaq, H., Shahzad, R., Iqbal, Z., 2019. Impact of transgenic crops on global food security: A Review. J. Agric. Res. 57(4):245-258.

Kumar, R., I. Ahad, S. Dorjey, U. Arifie and S.A. Rehman. 2017. A Review on Insect Pest Complex of Oats (*Avena sativa* L.). Int. J. Curr. Microbiol. App. Sci. 6(12):525-534.

Li, X., X. Cai, X. Ma, L. Jing, J. Gu, L. Bao, J. Li, M. Xu, Z. Zhang and Y. Li. 2016. Short-and long- term effects of wholegrain oat intake on weight management and glucolipid metabolism in overweight type-2 diabetics: A randomized control trial. Nutrients,

8:549.

Maneva, V., T. Savova and M. Marcheva. 2008. Propagation and species composition of aphids infesting oats. 44th Croatian and 4th International Symposium on Agriculture, Pp. 581-58.

Menon, R., T. Gonzalez, M. Ferruzzi, E. Jackson, D. Winderl and J. Watson. 2016. Oats from farm to fork. Adv. Food Nutr. Res. 77:1–55.

Muhammad, U.H., Z.A. Gurmani, S. Khan and A. Bakhsh. 2020. PARC Oat: A new Lodging-resistant, Late-maturing and High-yielding Variety of Oats (*Avena sativa* L.) for Pakistan. Pak. J. Agric. Sci. 33:601.

Niazi, I.A., S. Akhtar, S., Kohli, A. Naveed, S. Rauf and M. Shehzad. 2020. Oat (*Avena sativa* L.) advanced lines outperform existing cultivars for forage yield and its components under terminal heat stress. Pakistan J. Agric. Sci. 57:327–331.

Rana, M., S. Gupta, N. Kumar, R. Ranjan, R.P. Sah, R. Gajghate, K.K. Dwivedi and S. Ahmed. 2019. Genetic architecture and population structure of Oat Landraces (*Avena sativa* L.) using molecular and morphological descriptors. J. Tradit. Knowl. 18:439–450.

Rasane, P., A. Jha, L. Sabikhi, L., A. Kumar and V.S. Unnikrishnan. 2015. Nutritional advantages of oats and opportunities for its processing as value added foods-a review. J. Food Sci. Technol. 52:662–675.

Sarantis, S.D., N.M. Eren, B. Kowalcyk, R. Jimenez–Flores, V.B. Alvarez. 2021. Thermodynamic interactions of micellar casein and oat β-glucan in a model food system. Food Hydrocoll. 115:106559.

Sohail, S., M. Ansar, M. Skalicky, A. Wasaya, W. Soufan, T. A. Yasir, A.M. El-Shehawi, M. Brestic.

M.S. Islam, M.A. Raza and A. El-Sabagh. 2021. Influence of Tillage Systems and Cereals– Legume Mixture on Fodder Yield, Quality and Net Returns under Rainfed Conditions. Sustainability, 13:2172.

Steel, R.G., J.H. Torrie and D.A. Dickey. 1997. Principles and Procedures of Statistics: A Biological Approach; McGraw-Hill: New York, NY, USA.

Sterna, V., S. Zute and L. Brunava. 2016. Oat grain composition and its nutrition benefice. Agric. Sci. Procedia, 8:252–256.

Tukey, J. W. 1949. Comparing individual means in the analysis of variance. Biometrics. 5(2): 99- 114.

Vasilina, M., S. Todorka and M. Marina. 2009. Original scientific paper Propagation and species composition of aphids infesting oats Institute of agriculture – Karnobat, Bulgaria, Institute of plant genetic resources "K. Malkov" - Sadovo, Bulgaria.

Verma, C., J.D. Thanki, D. Singh and S. N. Chaudhari. 2016. Effect of nitrogen, bio-fertilizer and farm yard manure on yield and nutrient uptake in oat (*Avena sativa* L.). The bioscan. 11(1):499- 501.

William, H. 1990. Official Methods of Analysis of the Association of Official Analytical Chemists; AOAC International: Gaithersburg, MD, USA.

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