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Research article

Parent-offspring regression and intergeneration correlation analysis in powdery mildew resistance derived F_4 and F_5 generations of oat

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Abstract

The present investigation was undertaken to determine the intergeneration correlation and parent-offspring regression in F_4 and F_5 generations of seven different oat crosses which were grown during *Rabi* 2019-20 and 2020-21, respectively, at Experimental Farm of Fodder Section, CSKHPKV, Palampur. Correlation studies revealed a negative correlation between crude protein yield per plant with grain yield per plant in F_5 generation and a positive correlation between fresh fodder yield per plant and dry matter yield per plant in both generations, revealing crude protein yield as major forage yield component. F_4 generation progenies showed highly significant and positive values of intergeneration correlation and regression with F_5 generation progenies for grain yield per plant, crude protein yield per plant, harvest index and number of tillers per plant in most of the crosses, which indicated that the performance of plants on the basis of these traits is a reliable indicator of their performance in subsequent generations. Narrow sense heritability increased with the advancement of generation from F_4 to F_5, indicating the additivity of gene effects for the traits such as grain yield per plant, 100-grain weight, harvest index and crude protein yield per plant. Two progenies $P_{4-5-2-5}$ and $P_{4-5-2-8}$ of the cross HJ-8 × JPO-46 were resistant to powdery mildew disease in F_5 generation and the number of resistant plants was more in F_5 generation over F_4 generation which showed the efficiency of selection for resistance to powdery mildew.

Keywords: Narrow-sense heritability, Oat, Powdery mildew, Selection

Introduction

Oat (*Avena sativa* L.,) is an important cereal fodder crop constituent of the family Gramineae, which is generally grown as a dual-purpose crop in India. Among all cereals, oat ranks seventh after maize, wheat, rice, barley, sorghum and pearl millet at production of 25.50 Mt on 9.96 Mha and accounting for ~1% of global cereal production with potential in 'added value' feed markets (Sood *et al*., 2022). It is the most valuable multipurpose annual cereal crop cultivated globally for food and feed purposes (Priyanka *et al*., 2022). It is known locally as 'jai' and grown on the foothills of the Himalayas. It provides green fodder to livestock during its scarcity in the winter season and the surplus is converted into silage or hay to use during fodder deficit periods. It is preferred as feed by farmers for all types of livestock and grain is also a valuable feed for horses, dairy cows, poultry and young breeding animals. With the emergence of the growing dairy sector in our nation, oat has captivated the attention of breeders towards its nutritious quality fodder and grains with significant net energy gains as animal feed. Oat grains should have a high content of lipids, protein and carbohydrates while a low fiber content when are used for animal feed (Hizbai *et al*., 2012) whereas humans prefer grains that are low in lipids but high in protein and fiber (Ryan *et al*., 2007). Oat green fodder is composed of 20% dry matter, 10% crude protein, and 91% organic matter (Gupta *et al*., 2004). Oat protein ranges from 12 to 24% of hull-less oat kernel (groat) which is the highest among cereals (Lasztity, 1999) and is therefore of special interest to the animal feed industry.

Powdery mildew is a major foliar disease of cultivated oat (*Avena sativa* L.,) which is caused by the biotrophic fungus *Blumeria graminis* f. sp. *avenae*. In years with low and high disease pressure, grain yield losses ranged from 10 to 39% (Lawes and Hayes, 1965; Jones *et al*., 1987). The severity of this disease also causes a decline in grain protein and specific weight (Roderick *et al*., 2000). Since oats are generally produced as a low-input crop on less productive land, the most effective method for controlling powdery mildew is by growing resistant cultivars. Therefore, the selection of the powdery mildew resistance progenies in segregating generations seems to be the most cost-effective and environmentally sound strategy to manage the disease. However, due to low yield, its use as a crop is still limited (Arora *et al*., 2021; Rana *et al*., 2022). For this purpose, a systematic breeding programme is needed through the manipulation of yield components (Kumar *et al*., 2023).

The study of the correlation between traits that determine yield and quality can help in the indirect selection of their component traits. The intergeneration correlation coefficient gives an idea about the nature of gene action and thus tells about the effectiveness of single plant selection. Due to lesser sensitivity to environmental effects, the parent progeny correlation and regression between two generations is very useful for selection in segregating populations for the production of new and improved genotypes. Parent-offspring regression is being used as one of the most common methods for determining narrow-sense heritability of quantitative characters in plant populations, which is important to the plant breeder as the effectiveness of selection depends on the additive portion of genetic variance. Correlation studied by using parent-offspring regression helps in estimating the extent of transferring the genetic potentials of the character from one generation to another generation. Keeping this in mind, the present study was designed with the aim of evaluating segregating generations mainly for grain yield, powdery mildew resistance, other related traits and crude protein content. The main objective of the investigation was to find segregants having superior performance over checks.

Materials and Methods

The research material comprises of twenty-nine F_4 progenies derived from seven different crosses *viz*., PLP-1 × HJ-8, HJ-8 × JPO-46, HJ-8 × PLP-1, HJ-8 × EC528896, HJ-8 × *A. sterilis* cv. HFO-878, HJ-8 × KRR-AK-26 and PLP-1 × *A. byzantina* cv. HFO-60, which were performed in *Rabi*, 2016-17 at the Experimental Farm of Fodder Section, CSKHPKV, Palampur. Among the parents used in these crosses, PLP-1, JPO-46, KRR-AK-26, EC528896 and *A. sterilis* were resistant to powdery mildew disease, whereas HJ-8 is highly susceptible. During *Rabi*, 2019-20 the F_4 progenies possessing high yield and powdery mildew resistance were selected and evaluated in RBD over three replications with 3 rows of 2 m each having row-to-row spacing of 25 cm and 10 cm for plant to plant. Twenty-eight F_5 generation progenies were selected based on yield and powdery mildew resistance and evaluated in *Rabi*, 2020-21 following the same procedure undertaken during the evaluation of F_4 generation. The observations were recorded on five randomly selected plants taken from each progeny of each replication for different morphological, yield and its contributing traits *viz*., days to 50% flowering, plant height (cm), number of tillers per plant, number of leaves per plant, leaf area (cm^2), fresh fodder yield per plant (g), dry matter per cent, dry matter yield per plant (g), days to 75 % maturity, grain yield per plant (g), harvest index (%), 100 grain weight (g). At the biochemical aspect two traits *viz*., crude protein content (%) and crude protein yield per plant (g) were taken into account.

Statistical analysis: Regression coefficients (b) were calculated by regressing the mean values of a character in the progeny (F_5) upon the mean values of a character in the parent (F_4) for all the traits (Rao and Saxena, 1999). Intergeneration correlation coefficients (r) were calculated between selected F_4 and F_5 progenies as suggested by Lush (1940). Based on parent progeny regression, narrow sense heritability was calculated as suggested by Smith and Kinmann (1965) *i.e.* $h^2_{ns} = 2 \times b$. But, this method was not proved to be efficient as the heritability estimates from this method was found to be more than 1 (or 100%). This weakness of the method was tackled by using a correction formula (Smith and Kinmann, 1965) *i.e.* multiplicative factor of 8/15; $h^2_{ns} = 8/15 * b$ (for F_4- F_5). The percentage of superior segregants in a particular cross was recorded by calculating the number of plants exceeding a mean value of best check to the total number of plants in a cross. Correlations between the studied traits were evaluated using the corrplot package of R 4.3.3 software.

Results and Discussion

Correlation studies: Inter-relationship between crude protein with grain yield and related traits was revealed using a correlation matrix in the form of corrplot (Fig 1). The range of correlation coefficient is shown in the vertical index bar. Correlation studies revealed that crude protein yield per plant showed a negative correlation with grain yield per plant in F_5 generation and a positive correlation with tillers per plant, leaves per plant, leaf area, fresh fodder yield per plant, dry matter percent and dry matter yield per plant in both generations. These results indicated that crude protein yield per plant, tillers per plant, leaves per plant, leaf area, dry matter percent and dry matter yield per plant played chief roles as major forage yield components. Therefore, the selection of these traits would offer the scope for improvement in fresh fodder yield. Devi *et al.* (2018) also reported a significant correlation between tillers per plant, leaves per plant, crude protein yield per plant and dry matter yield per plant in F_2, F_3, and F_4 generations of oat. Mut *et al.* (2016) also revealed significant negative correlations of grain yield with crude protein content. Wagh *et al.* (2018) in a study, observed the highest positive direct effect and significantly positive correlation of leaf width and crude protein content with green forage yield.

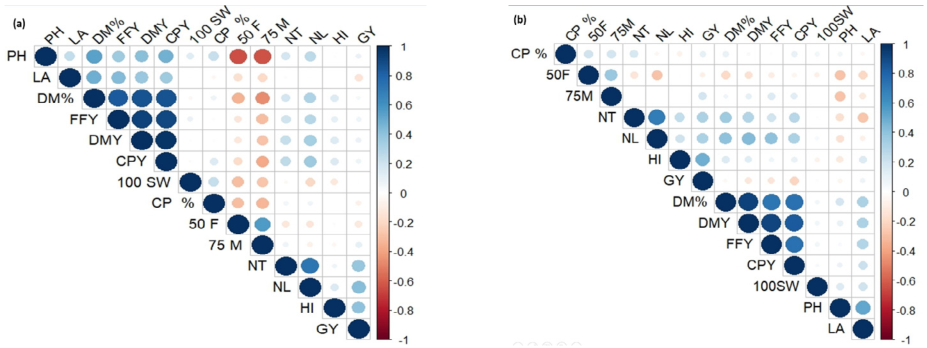

Fig 1. Correlation matrix in the form of corrplot using the studied parameters of oat in F_4 (a) and F_5 (b) generations

***Intergeneration correlation studies by using parent-offspring regression*:**
The results from this study revealed about the extent of the genetic potential of the character transferred from one generation to other generation. The values of the parent-offspring regression coefficient and intergeneration correlation between F_4 and F_5 generations were found to be significantly positive for different characters from all of the crosses (Table 1; Fig 2). The results showed significantly positive regression and intergeneration correlation coefficient values in the cross PLP-1 × HJ-8 for five traits *viz*., days to 50% flowering (0.88, 0.90), plant height (0.66, 0.59), leaf area (1.31, 0.76), dry matter per cent (0.57, 0.61) and crude protein yield per plant (0.73, 0.68); in the cross HJ-8 × JPO-46 for harvest index (1.55, 0.86); in the cross HJ-8 × PLP-1 for three traits *viz*., number of tillers per plant (0.65, 0.63), grain yield per plant (0.78, 0.90) and harvest index (1.01, 0.89); in the cross HJ-8 × EC528896 for five traits *viz*., grain yield per plant (1.80, 0.96), 100 seed weight (1.74, 0.58), crude protein yield per plant (1.30, 0.89), fresh fodder yield per plant (0.71, 0.70) and dry matter yield per plant (0.33, 0.57); cross HJ-8 × *A. sterilis* for crude protein yield per plant (0.57, 0.79); in the cross HJ-8 × KRR-AK-26 for number of leaves per plant (0.54, 0.66) and crude protein content (0.36, 0.61); in the cross PLP-1 × *A. byzantina* for number of tillers per plant (0.61, 0.61). The traits showing the maximum value of regression coefficient are mostly governed by additive gene action and are suitable for selection in the advanced generations of segregating progenies to identify the lines that will give higher grain yield per plant. Therefore, the performance of the plants in F_4 generation for all the above traits is a reliable indicator of the performance of their progeny in subsequent generations. Similar findings were also reported by Wagoire *et al*. (1999) for grain yield in spring wheat, Sultana *et al*. (2002) and Laala *et al*. (2017) for plant height in wheat; Kumar *et al*. (2020) for plant height, 100-grain weight, number of tillers per plant, grain yield per plant and harvest index in wheat and Rani *et al*. (2021) for all the characters of two wheat crosses in F_4 and F_5 generations.

***Narrow sense heritability*:** As narrow sense heritability includes only the fixable components, *i.e*. additive and additive × additive variances, the chances of improving the characters showing high values of narrow-sense heritability are high through selection (Table 2). Highest narrow sense heritability was observed in cross PLP-1 × HJ-8 for the traits *viz*., leaf area (69.65) followed by days to 50% flowering (46.77), crude protein yield per plant (39.15), days to 75% maturity (36.85), plant height (35.42), number of leaves per plant (33.87) and dry matter per cent (30.29); in cross HJ-8 × JPO-46 for harvest index (82.83) followed by crude protein yield per plant (33.17), plant height (32.59) and leaf area (30.19); in cross HJ-8 × PLP-1 for harvest index (53.65) followed by grain yield per plant (41.65), number of tillers per plant (34.77) and fresh fodder yield per plant (20.27); in cross HJ-8 × EC528896 for grain yield per plant (96.00) followed by 100 grain weight (92.96), crude protein content (69.39), days to 75% maturity (63.68) and fresh fodder yield per plant (37.76); in cross HJ-8 × *A. sterilis* for crude protein yield per plant (30.13) followed by crude protein content (24.53), plant

Table 1. Regression (b) and intergeneration (r) correlation coefficient values between F_4- F_5 generations for various traits in oat

Characters		PLP-1 × HJ-8	HJ-8 × JPO-46	HJ-8 × PLP-1	HJ-8 × EC528896	HJ-8 × *A. sterilis*	HJ-8 × KRRRAK-26	PLP-1 × *A. byzantina*
Days to 50% flowering	r	**0.90***	-0.43	-0.27	-0.48	-0.01	-0.19	0.22
	b	**0.88***	-0.31	-0.30	-0.71	0.00	-0.19	0.06
Plant height (cm)	r	**0.59***	0.43	0.02	-0.19	0.34	-0.79	-0.62**
	b	**0.66***	0.61	0.01	-0.20	0.42	-0.76	-0.07**

Tillers per plant	**r**	0.00	-0.18	**0.63****	0.01	0.19	0.19	**0.61****
	b	-0.01	-0.09	**0.65****	0.01	0.35	0.33	**0.61****
Leaves per plant	**r**	0.41	-0.02	0.21	0.48	-0.17	**0.66****	-0.45
	b	0.64	-0.02	0.11	0.25	-0.18	**0.54****	-0.17
Leaf area (cm^2)	**r**	**0.76****	0.13	0.06	-0.72**	-0.38	0.00	-0.39
	b	**1.31****	0.57	0.05	-0.77**	-1.16	0.01	-0.31
Fresh fodder yield per plant (g)	**r**	0.38	-0.37	0.47	**0.70****	-0.20	-0.90**	0.28
	b	0.34	-0.06	0.38	**0.71****	-0.42	-0.22**	0.22
Dry matter per cent	**r**	**0.61****	0.12	0.45	0.30	-0.20	-0.76**	-0.53*
	b	**0.57****	0.02	0.27	0.19	-0.23	-0.48**	-0.31*
Dry matter yield per plant (g)	**r**	0.28	-0.18	0.44	**0.57****	-0.03	-0.83**	-0.22
	b	0.18	-0.02	0.26	**0.33****	-0.05	-0.45**	-0.16
Days to 75% maturity	**r**	0.71	0.61	-0.26	0.75	-0.72	0.47	0.56
	b	0.69	0.22	-0.20	1.19	-0.78	0.16	0.30
Grain yield per plant (g)	**r**	-0.35	-0.34	**0.90****	**0.96****	0.19	0.01	-0.76**
	b	-0.07	-0.21	**0.78****	**1.80****	0.28	0.00	-0.12**
Harvest index (%)	**r**	-0.58*	**0.88****	**0.89****	-0.31	-0.40	0.16	-0.63**
	b	-0.55*	**1.55****	**1.01****	-1.24	-1.03	0.05	-0.49**
100 grain weight (g)	**r**	-0.21	-0.21	-0.25	**0.58***	-0.59*	-0.23	0.33
	b	-0.06	-0.83	-0.79	**1.74***	-0.14*	-0.09	0.47
Crude protein content (%)	**r**	-0.77**	0.29	-0.25	-0.93**	0.17	**0.61****	-0.33
	b	-0.73**	0.62	-0.28	-0.76**	0.46	**0.36****	-0.12
Crude protein yield per plant (g)	**r**	**0.68****	0.14	0.26	**0.89****	**0.79****	-0.98**	-0.24
	b	**0.73****	0.02	0.12	**1.30****	**0.57****	-0.55**	-0.03

Table 2. Narrow sense heritability based on parent-progeny regression between F_4- F_5 generations for various traits in oat

Characters	**PLP-1 × HJ-8**	**HJ-8 × JPO-46**	**HJ-8 × PLP-1**	**HJ-8 × EC528896**	**HJ-8 × *A. sterilis***	**HJ-8 × KRRRAK-26**	**PLP-1 × *A. byzantina***
Days to 50% flowering	46.77	-16.69	-15.79	-37.92	-0.16	-9.92	3.09
Plant height (cm)	35.41	32.59	0.32	-10.67	22.13	-40.43	-3.79
Tillers per plant	-0.32	-4.75	34.77	0.43	18.40	17.44	32.43
Leaves per plant	33.87	-0.85	5.65	13.28	-9.81	28.91	-8.85
Leaf area (cm^2)	69.65	30.19	2.83	-40.85	-61.60	0.43	-16.75
Fresh fodder yield per plant (g)	17.87	-2.93	20.27	37.76	-22.45	-11.57	11.52
Dry matter per cent	30.29	0.91	14.24	9.97	-12.37	-25.76	-16.53
Dry matter yield per plant (g)	9.60	-1.07	14.03	17.44	-2.88	-23.89	-8.53
Days to 75% maturity	36.85	11.84	-10.77	63.68	-41.65	8.27	15.73
Grain yield per plant (g)	-3.79	-10.99	41.65	96.00	14.77	0.21	-6.13
Harvest index (%)	-29.17	82.83	53.65	-66.03	-54.72	2.61	-26.35
100 grain weight (g)	-2.99	-44.48	-42.03	92.96	-7.57	-4.85	25.12
Crude protein content (%)	-38.88	33.17	-14.93	-40.53	24.53	18.99	-6.13
Crude protein yield per plant (g)	39.15	0.91	6.24	69.39	30.13	-29.17	-1.44

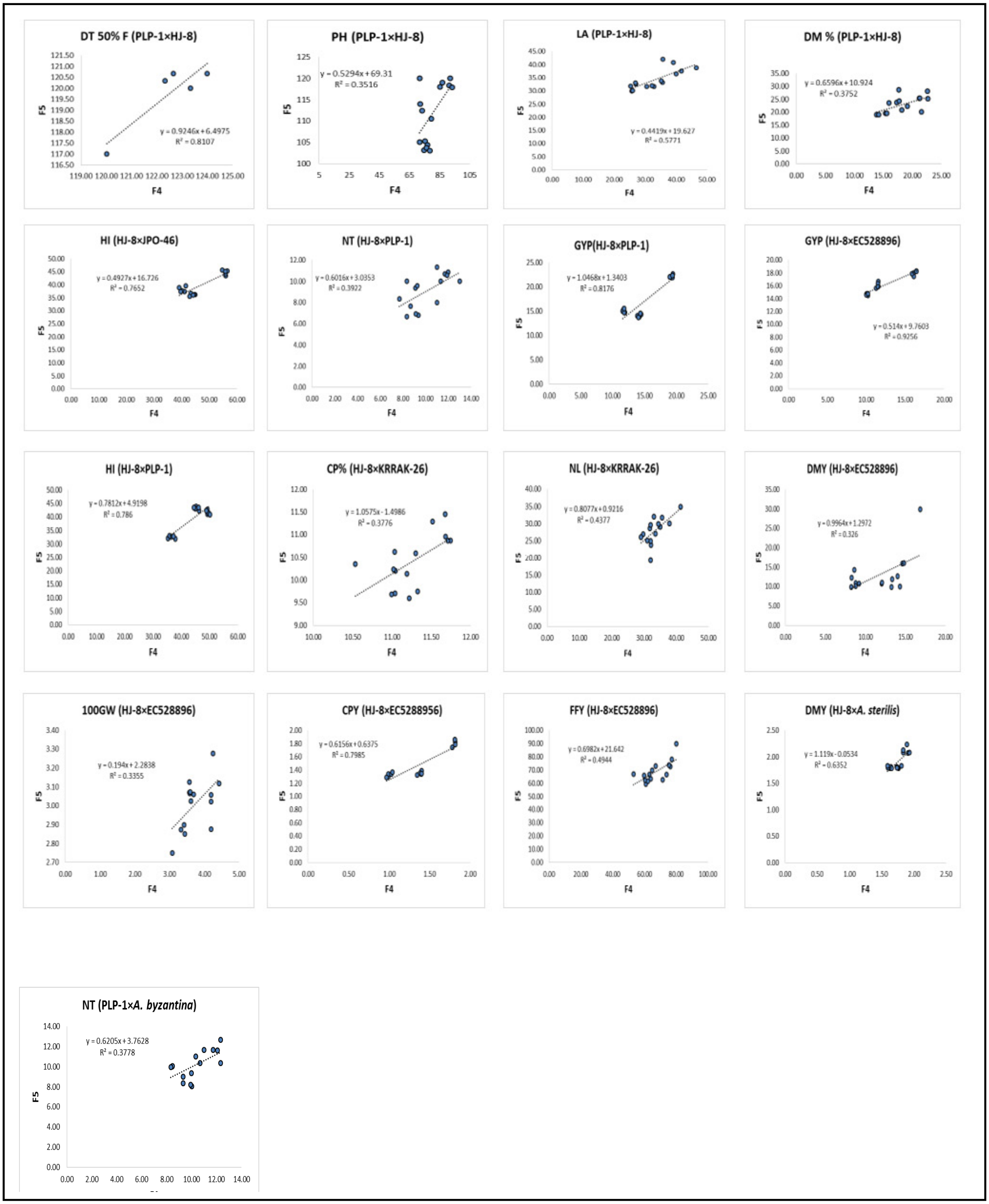

Fig 2. Graphical representation of significant positive parent-offspring regression for various yield, their component and quality traits in different crosses of oat; where DT 50%: Date to 50% flowering; PH: Plant height (cm); LA: Leaf area; DM%: Dry matter; HI: Harvest index; NT: No. of tillers per plant; GYP: Grain yield per plant; CP%: Crude protein; NL: No. of leaves per plant; DMY: Dry matter yield per plant; 100 GW: 100 Grain weight; CPY: Crude protein yield; FFY: Fresh fodder yield;

height (22.13), number of tillers per plant (18.40) and grain yield per plant (14.77); in cross HJ-8 × KRR-AK-26 for number of leaves per plant (28.91) followed by crude protein content (18.99) and number of tillers per plant (17.44); in cross PLP-1 × *A. byzantina* for number of tillers per plant (32.43) followed by 100 grain weight (25.12) and days to 75% maturity (15.73). Rani *et al.* (2021) also reported high narrow sense heritability for a number of grains per ear, grain weight per ear and grain yield per plant in two wheat crosses in F_4 and F_5 generations. Kumar *et al.* (2018) reported that the traits showing more than 30% narrow sense heritability could be rewarding for further improvement in grain yield.

Powdery mildew resistance: The data on the disease reaction of all the progenies in seven crosses were recorded separately (Fig 3). It was found that the number of resistant plants was more in F_5 generation over F_4 generation which showed the efficiency of selection for resistance to powdery mildew. In F_4 generation, 16 progenies of different crosses *viz*., PLP-1 × HJ-8 ($P_{2\text{-}7\text{-}2}$, $P_{5\text{-}6\text{-}2}$, $P_{7\text{-}3\text{-}3}$), HJ-8 × JPO-46 ($P_{1\text{-}4\text{-}8}$, $P_{2\text{-}10\text{-}3}$, $P_{4\text{-}5\text{-}2}$), HJ-8 × PLP-1 ($P_{3\text{-}7\text{-}3}$, $P_{6\text{-}12\text{-}4}$), HJ-8 × EC528896 ($P_{2\text{-}4\text{-}6}$, $P_{8\text{-}5\text{-}7}$), HJ-8 × KRR-AK-26 ($P_{1\text{-}7\text{-}5}$, $P_{6\text{-}13\text{-}2}$), HJ-8 × *A. sterilis* ($P_{8\text{-}7\text{-}6}$, $P_{12\text{-}5\text{-}10}$) and PLP-1 × *A. byzantina* ($P_{5\text{-}11\text{-}6}$, $P_{11\text{-}2\text{-}4}$) along with check: PLP-1 found to be moderately resistant. However, nine progenies from crosses *viz*., PLP-1 × HJ-8 ($P_{4\text{-}1\text{-}7}$, $P_{8\text{-}4\text{-}8}$), HJ-8 × JPO-46 ($P_{6\text{-}5\text{-}7}$), HJ-8 × EC528896 ($P_{8\text{-}5\text{-}7}$), HJ-8 × *A. sterilis* ($P_{3\text{-}2\text{-}3}$, $P_{10\text{-}4\text{-}7}$, $P_{13\text{-}2\text{-}9}$) and PLP-1 × *A. byzantina* ($P_{7\text{-}9\text{-}3}$, $P_{10\text{-}1\text{-}5}$) revealed moderately susceptible response. Four progenies *viz*., HJ-8 × PLP-1 ($P_{1\text{-}4\text{-}5}$, $P_{4\text{-}2\text{-}1}$), HJ-8 × EC528896 ($P_{3\text{-}7\text{-}10}$) and HJ-8 × KRR-AK-26 ($P_{9\text{-}4\text{-}4}$) were susceptible, while checks: HJ-8 and Kent observed to be highly susceptible.

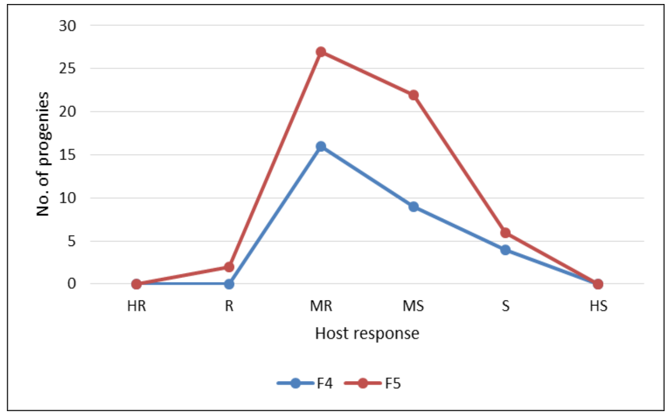

Fig 3. Reaction of plants to powdery mildew in F_4 and F_5 generation progenies

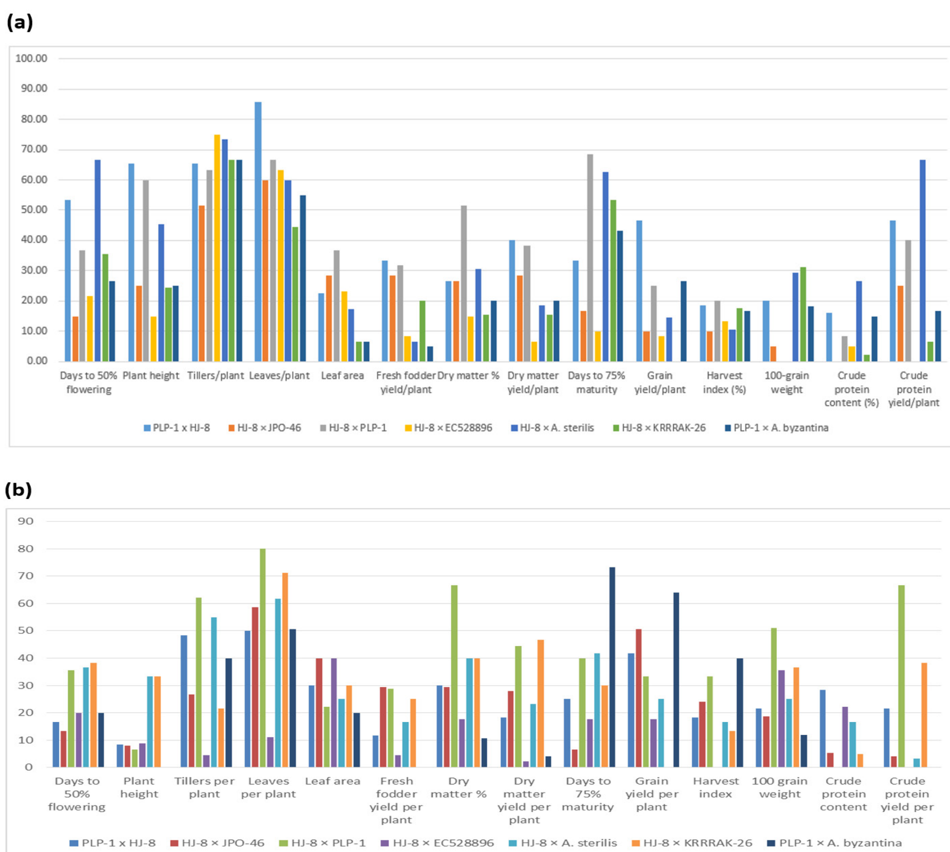

Fig 4. Percentage of superior segregants over best check in F_4 (a) and F_5 (b) generations of oat

In F_5 generation, results revealed that two progenies of the cross HJ-8 × JPO-46 ($P_{4-5-2-5}$, $P_{4-5-2-8}$) along with check PLP-1 showed resistance response, whereas 11 progenies of different crosses, namely PLP-1 × HJ-8 ($P_{2-7-2-4}$, $P_{2-7-2-6}$), HJ-8 × JPO-46 ($P_{2-10-3-6}$, $P_{4-5-2-6}$), HJ-8 × PLP-1 ($P_{3-7-3-2}$, $P_{6-12-4-5}$), HJ-8 × *A. sterilis* ($P_{8-7-6-11}$, $P_{12-5-10-6}$) and PLP-1 × *A. byzantina* ($P_{5-11-6-5}$, $P_{5-11-6-7}$, $P_{11-2-4-2}$) were moderately resistant. However, 13 progenies from the crosses such as PLP-1 × HJ-8 ($P_{5-6-2-8}$, $P_{7-3-3-2}$), HJ-8 × JPO-46 ($P_{2-10-3-9}$), HJ-8 × PLP-1 ($P_{6-12-8-3}$), HJ-8 × EC528896 ($P_{8-5-7-2}$, $P_{8-5-7-4}$), HJ-8 × *A. sterilis* ($P_{3-2-3-10}$, $P_{12-5-10-8}$), HJ-8 × KRR-AK-26 ($P_{7-3-3-2}$, $P_{6-13-2-2}$, $P_{6-13-2-4}$), and PLP-1 × *A. byzantina* ($P_{5-11-6-3}$, $P_{11-2-4-3}$) observed to be moderately susceptible. Two progenies of the crosses HJ-8 × EC528896 ($P_{2-4-6-3}$) and HJ-8 × KRR-AK-26 ($P_{1-7-5-5}$) were susceptible, while checks HJ-8 and Kent revealed highly susceptible responses. Okon and Ociepa (2017) observed resistance in two of seven tested genotypes of wild *A. sterilis* species and in a study by Malannaver and Banyal (2020), maximum colony size was observed in HJ-8 as compared to slow mildewers in powdery mildew.

***Superior segregants over best check in F_4 and F_5 generations*: ** The feasibility of selecting superior segregants is reliant on the breeder's ability to fix them in early generations. One of the objectives of this research was to find superior segregants in F_4 and F_5 generations for various traits, with values exceeding the mean values of the better check for the respective trait. In the F_4 and F_5 generations, the graphical representations of the percentage of superior segregants for various crosses were also recorded (Fig 4). The best segregants for grain yield per plant were shown by the cross PLP-1× HJ-8 in both generations. The crosses, HJ-8 × JPO-46 and HJ-8 × PLP-1 showed an increment in superiority for both fresh fodder and grain yield per plant in F_5 generation over F_4 generation, whereas an increment for dry matter yield per plant and dry matter percent was shown by HJ-8 × KRR-AK-26 and grain yield per plant by PLP-1 × *A. byzantina*. For crude protein per plant, cross HJ-8 × PLP-1 showed the highest frequency of superior segregants and there was also an increment in superiority from F_4 to F_5 generation. However, superiority remains same for various fodder and grain yield traits in cross HJ-8 × *A. sterilis*, while cross HJ-8 × EC528896 was found superior for only few traits in both the generations.

Conclusion

It was concluded that crude protein yield per plant had a negative correlation with grain yield per plant and a positive correlation with fresh fodder yield per plant and dry matter yield per plant in both generations, revealing crude protein yield as a major forage yield component. Positive significant values of intergeneration correlation and regression for grain yield per plant in the crosses HJ-8 × PLP-1 and HJ-8 × EC528896, for both fresh fodder yield and dry matter yield in cross HJ-8 × EC528896 and for crude protein yield per plant in crosses HJ-8 × EC528896 and HJ-8 × *A. sterilis* indicated the importance and effectiveness of selection for these traits. Grain yield per plant, 100 grain weight and harvest index depicted a high value of narrow sense heritability based on parent-offspring regression and thus selection among segregants based on phenotypic values of these traits is effective as these characters are governed by additive variance. The best segregants for grain yield per plant were shown by the cross PLP-1 × HJ-8 in both generations, and crosses HJ-8 × JPO-46 and HJ-8 × PLP-1 showed an increment in both grain yield and fresh fodder yield over the previous generation. For crude protein per plant, cross HJ-8 × PLP-1 showed the highest frequency of superior segregants and there was also an increment in superiority from F_4 to F_5 generation. Two progenies $P_{4-5-2-5}$ and $P_{4-5-2-8}$ of the cross HJ-8 × JPO-46, were resistant to powdery mildew disease in F_5 generation, and the number of resistant plants was more in F_5 generation over F_4 generation, which showed the efficiency of selection for resistance to powdery mildew.

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