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Research article

Seed yield response of fodder oat varieties to row spacing and seed rate in north-west parts of India

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Abstract

Oat (*Avena sativa* L.) is an important *rabi* cereal fodder crop of north-west India. Recently, a number of fodder oat varieties have been released in country-wide adaptability. However, limited information on optimal row spacing and seed rate for these fodder oat varieties in seed production system is available especially in the north-western parts of the country, where it is primarily grown for fodder purpose. Hence, field experiments were conducted during winter season from 2016-17 to 2019-20 to evaluate the effects of row spacing and seed rate on growth, yield attributes and seed yield of two fodder oat varieties. When averaged across years, there was 10.4% increase in oat seed yield with 30 cm row spacing over 20 cm row spacing. Higher oat seed yield in wide rows during all the years of the study was mainly attributed to more number of effective tillers, seed per panicle and panicle length. The 1000-seed weight, however, remained unaffected by the row spacing. An increase in seed rate from 37.5 to 62.5 kg/ha resulted in a decrease in seed yield and various yield attributes. However, there was no significant interaction between row spacing and seed rate for seed yields. In conclusion, for reaping maximum oat seed yield, the fodder oat varieties should be planted at 30 cm row spacing and with 37.5 kg/ha seed rate.

Keywords: Fodder oat, Row spacing, Seed rate, Seed yield, Tillering

Introduction

Oat (*Avena sativa* L.) is an important cereal crop ranking sixth in the world cereal production statistics following wheat, maize, rice, barley and sorghum (FAOSTAT, 2021). It has multi-purpose uses- a cereal crop, a feed grain, green or conserved fodder. In India, it is being cultivated on an area of 10,000 hectares primarily in north-western parts of the country (Dar *et al*., 2014; Singh and Chauhan, 2017). It has rapid growth and high palatability and is a rich source of energy, protein, and minerals. However, despite its popularity, the shortage of seeds with high quality is a big hindrance in the further spread and distribution of oat in the country (Kumar *et al*., 2006; Kumar *et al*., 2023). Due to the lack of recommendations for optimum seed rate and row spacing for seed crop of these fodder oat genotypes, the seed yield potential of these genotypes is not being harnessed fully by the farmers or few seed production agencies that are engaged in its seed production (Palsaniya *et al*., 2015; Mir *et al*., 2018). As fodder oat needs to be produced from seed, so oat seed production system is an important venture requiring agronomic practices different from those recommended for fodder oat.

Among the different agronomic approaches, the optimal row spacing and seed rate are important approaches which can be used to enhance seed or grain yield by optimizing tillering capacity and other yield components through efficient utilization of available resources (Ayaz *et al*., 1999; Hussain *et al*., 2012). Row spacing affects the crop productivity by altering the plant canopy architecture, photosynthetic and assimilation capacity of leaves and source-sink relationship of crop plants (Samani *et al*., 1999). There is severe intra-species competition in narrow rows, while there is inefficient utilization of growth resources, solar radiation in particular by plants grown in a wider row spacing leading to poor radiation use efficiency. Likewise, seeding rate is an important factor for optimizing an ideal plant population so that the crop's ability to produce effective tillers can be increased. Studies about these agronomic practices in Punjab, India are limited despite new fodder oat varieties being released on a regular basis (Ahmad *et al*., 2015; Kapoor *et al*., 2022). Therefore, the present investigation was planned to examine the influence of row spacing and seed rate on plant growth, tillering capacity, yield attributes and seed yield in two fodder oat varieties.

Materials and Methods

Experimental site and design: This study was conducted at Forage Research Farm, Punjab Agricultural University, Ludhiana, India (30°54´N, 75°48´E and 247 m above sea level) during the winter seasons of 2016-17, 2017-18, 2018-19 and 2019-20. The climate of the region is subtropical and semi-arid. The soil of experimental field was sandy loam in texture and contained 218 kg/ha available N, 39.8 kg/ha available P and 127.5 kg/ha available K. The experiment was arranged in a split plot design with a net plot size of 4 x 3 m for each experimental unit and with three replications. Two fodder oat varieties (OL 10 and OL 11) and two row spacings (20 and 30 cm) were kept in main plots and three seed rates (37.5, 50, and 62.5 kg/ha) in sub-plots.

Crop husbandry: A heavy (~10 cm) pre-sowing irrigation was applied to get the optimum soil moisture status. At field capacity, the field was prepared by ploughing the field twice with a tractor-mounted cultivator followed by planking. The crop was sown around mid-November during all the four years of study, with a manual hand-drill as per the different treatments. Fertilizers were applied at 50 kg N/ha and 20 kg P_2O_5/ha using urea and single super phosphate, respectively, as sources. Whole phosphorus and a half dose of nitrogen were applied at sowing time, and a half dose of nitrogen was applied with the first irrigation. In total, four irrigations were applied to avoid drought stress. Other agronomic practices were adopted to keep the crop free from weeds, insects and diseases. The mature crop was harvested when the straw turned yellow and the grains were ripe.

Biometric observations: The plant height was recorded at maturity from 10 randomly selected plants in each plot. Height was measured using a meter rod from the ground to the base of the panicle, averaged out and then expressed in centimeters. Total effective tillers were recorded from one meter row length in two rows randomly in each plot and averaged out and then presented as number of tillers per square meter. The length of ten randomly selected panicles from each plot at harvest was measured with a ruler and averaged to record panicle length. Ten panicles at random were collected from each plot and threshed manually and the total number of seed was counted and then averaged to record number of seed per panicle. Thousand seed weight was determined after harvest by taking five random samples of 1000-seeds from the seed lot of each net plot; weighed after sun-drying and averaged to record 1000-seed weight. The crop was harvested manually with sickles when the plants reached the stage of full maturity. After harvest, the produce was first sun-dried and then weighed to record the biological yield and thereafter threshed by a mechanical thresher to separate the seed and straw. Seed were weighed to record the seed yield with moisture content adjusted to 12%. The harvest index (HI) was calculated as the ratio between seed yield and biological yield and expressed in percent. The data collected on various parameters were statistically analyzed by using Fisher's analysis of variance technique and the least significant difference test (LSD) at the 0.05 level of probability was used to compare the differences among the treatment means.

Results and Discussion

Yield components: The two oat varieties did not exert any significant influence on the plant height and the number of effective tillers per m^2 during different cropping seasons (Table 1). Plant height of oat was not affected by row spacing in all the study years except for 2019-20. However, plants tended to be taller in the closer row spacing (Table 1). The effect of seed rate on plant height was significant in all the years except in 2019-20. Plant height increased with increasing seed rate and was the lowest at 37.5 kg/ha seed rate. The number of effective tillers per m^2 was significantly influenced by row spacing treatments and on an average of four years, there was approximately 73 more number of effective tillers per m^2 with row spacing of 30 cm compared to 20 cm indicating the efficient utilization of various growth factors like solar radiation, moisture and nutrients by the tall oat varieties.The number of effective tillers per m^2 was found to decrease significantly with increasing seed rate and highest number of effective tillers per m^2 was recorded with 37.5 kg/ha seed rate. On an average, effective tillers per m^2 with 37.5 kg/ha seed rate increased by 12.7% over 50 kg/ha seed rate and by 21.7% over 62.5 kg/ha seed rate.

The two oat varieties behaved almost similarly with regard to the yield attributes of panicle length, seed per panicle and 1000-seed weight (Table 2). The row spacing treatment significantly affected panicle length and number of seed per panicle. On pooled mean basis, panicle length increased by 4.1% and seed per panicle increased by 3.5% in 30 cm row

Table 1. Effect of different treatments on plant height and number of effective tillers of oat

Treatments	Plant height (cm)				Number of effective tillers/m^2			
	2016-17	2017-18	2018-19	2019-20	2016-17	2017-18	2018-19	2019-20
Varieties								
OL 10	119.1	139.4	141.6	110.4	217.2	208.1	202.2	222.0
OL 11	119.6	138.0	145.9	114.5	213.5	213.5	205.9	231.6
LSD (P<0.05)	NS	NS	NS	3.3	NS	NS	NS	3.1
Row spacing (cm)								
20	120.5	139.0	145.6	115.9	175.8	171.6	176.0	187.1
30	118.1	138.4	141.8	109.0	254.9	249.5	232.1	266.6
LSD (P<0.05)	NS	NS	NS	3.3	7.4	12.3	28.5	3.2
Seed rate (kg/ha)								
37.5	116.0	134.8	141.9	109.6	238.5	240.5	225.8	244.1
50	120.0	135.4	142.1	114.6	210.8	205.8	202.1	223.1
62.5	122.0	146.0	147.2	113.2	196.7	185.3	184.2	213.4
LSD (P<0.05)	4.1	3.1	4.3	NS	19.1	16.5	18.6	7.8

NS: Non-significant

Table 2. Effect of different treatments on panicle length, seed per panicle and 1000-seed weight of oat

Treat-ments	Panicle length (cm)				Seed per panicle				1000-seed weight (g)			
	2016-17	2017-18	2018-19	2019-20	2016-17	2017-18	2018-19	2019-20	2016-17	2017-18	2018-19	2019-20
Varieties												
OL 10	31.2	32.7	32.8	31.2	96.8	97.2	96.4	123.3	30.9	31.3	31.2	30.3
OL 11	32.5	33.8	33.8	33.1	99.5	99.8	99.8	151.1	31.5	31.8	31.5	31.4
LSD (P<0.05)	NS	NS	NS	1.0	NS	1.9	NS	6.4	NS	NS	NS	0.7
Row spacing (cm)												
20	31.1	32.9	32.7	31.4	97.4	95.9	96.6	134.5	31.4	31.4	32.1	30.4
30	32.7	33.6	34.0	32.8	98.9	101.0	99.5	140.0	31.0	31.7	30.6	31.3
LSD (P<0.05)	1.1	NS	1.2	1.0	NS	1.9	NS	NS	NS	NS	1.1	0.7
Seed rate (kg/ha)												
37.5	34.6	35.1	33.6	34.2	103.0	101.0	101.4	183.8	32.6	33.7	33.2	31.7
50	31.8	33.2	33.3	32.3	96.7	100.5	96.8	127.2	32.0	30.9	32.3	31.2
62.5	29.3	31.5	32.9	29.8	94.8	94.0	96.1	100.6	29.0	30.1	28.6	29.8
LSD (P<0.05)	2.2	2.3	NS	1.3	6.2	5.1	NS	9.8	2.0	1.5	1.1	NS

NS: Non-significant

spacing compared with 20 cm row spacing across the four cropping seasons. Conversely, 1000-seed weight between the two row spacing treatments was inconsistent in performance and did not show a definite trend in the four cropping seasons. Oat seed rate also significantly affected panicle length, number of seed per panicle and 1000-seed weight and there was a constant descending trend in these yield components with increasing seed rate. In oat, among the different yield components, effective tillers and number of seed per panicle were the predominant factors contributing to yield formation, while seed weight was of lesser significance (Finnan and Spink, 2017). Sowing of a crop with the most favorable row spacing as well as planting density might be helpful to maximize the effective tiller production and other yield attributing components (Hussain *et al.*, 2012).

Yield: The effect of row spacing on seed yield was consistent across four cropping seasons. Seed yield of oat sown with 30 cm row spacing was greater than the crop sown with 20 cm row spacing by 10.2% (248 kg/ha) in 2016-17, by 9.9% (256 kg/ha) in 2017-18, by 12.4% (312 kg/ha) in 2018-19 and by 9.1% (256 kg/ha) in 2019-20 (Table 3). Lafond *et al*. (2013) also confirmed that wide row spacing up to 35 cm was feasible for oat seed production. However, Al dulaimi *et al*. (2021) reported higher oat grain yield at 20 cm row spacing. This could be because of the contrasting oat genotype being used in their study which was a semi-dwarf oat variety, whereas the varieties used in this study were tall genotypes and prone to lodging at closer spacing. Oat seed yield varied significantly among the three seed rates in each of the cropping seasons (Table 3). The seed rate of 37.5 kg/ha consistently produced the highest seed yield, whereas seed rate of 62.5 kg/ha produced the lowest seed yield in all the study years. On an average of the four seasons, seed yield of oat sown with 37.5 kg/ha was 12.1 and 20.9% higher than the crop sown with 50 and 62.5 kg/ha seed rate, respectively. However, Kumar *et al*. (2006) reported no significant difference in seed yield of oat across the three seed rates of 60, 80 and 120 kg/ha but still seed yield was higher with the lowest seed rate used. In the present study, it was shown that there was a positively strong relationship between number of seed per panicle and seed yield (Table 4). Hence, increased seed yield might be attributed to significant increase in effective tillers and seed number per panicle in 30 cm row spacing and with 37.5 kg/ha seed rate. Wide row spacing facilitated aeration and light penetration into the plant canopy for optimizing rate of photosynthesis which was reflected in increase in the yield components and finally in increased seed yield. The interaction between row spacing and seed rate for seed yield was not significant (Table 5). More biological yield was recorded by the crop sown in closer rows than the crop sown in wide row spacing, however, the differences were not statistically significant.

Table 3. Effect of different treatments on seed and biological yield, harvest index and benefit: cost ratio of oat

Treat-ments	Seed yield (kg/ha) 2016-17	2017-18	2018-19	2019-20	Biological yield (kg/ha) 2016-17	2017-18	2018-19	2019-20	Harvest index (%) 2016-17	2017-18	2018-19	2019-20	Bene-fit: cost (pooled)
Varieties													
OL 10	2632	2496	2437	2820	12443	15100	15882	9935	21.6	16.7	15.6	28.6	2.15
OL 11	2485	2914	2893	3051	13089	16270	17492	10767	19.3	18.1	16.7	28.6	2.41
LSD (P<0.05)	NS	227	170	NS	NS	NS	NS	NS	2.2	NS	NS	NS	0.13
Row spacing (cm)													
20	2434	2577	2509	2808	13090	15630	16743	10581	19.0	16.7	15.1	27	2.25
30	2682	2833	2821	3064	12442	15741	16631	10121	21.8	18.1	17.2	30.3	2.31
LSD (P<0.05)	194	227	170	NS	NS	NS	NS	NS	2.2	NS	2.1	NS	NS
Seed rate (kg/ha)													
37.5	2907	2983	2902	3198	12235	15206	15950	10258	24.0	19.8	18.3	31.4	2.41
50	2540	2711	2567	2872	12058	15528	16617	10159	21.2	17.4	15.6	28.5	2.22
62.5	2227	2422	2525	2738	14005	16322	17494	10637	16.0	15.0	14.5	25.9	2.22
LSD (P<0.05)	326	303	212	278	1091	NS	NS	NS	2.6	2.1	1.8	2.6	0.11

NS: Non-significant

Table 4. Correlation coefficients between seed yield and yield components across different treatments and seasons

Treatments	Seed yield (kg/ha)	Number of effective tillers/m^2	Seed/ panicle	Panicle length (cm)	1000-seed weight (g)
Seed yield (kg/ha)	1				
Number of effective tillers/m^2	0.739**	1			
Seed/ panicle	0.914**	0.501^{NS}	1		
Panicle length (cm)	0.904**	0.676*	0.872**	1	
1000-seed weight (g)	0.704*	0.310^{NS}	0.843**	0.792**	1

NS: Non-significant; *(P<0.05); **(P<0.01)

Table 5. Interaction effect of different treatments on seed yield of oat (data pooled over the years)

Varieties	Row spacing 20 cm			Row spacing 30 cm		
	Seed rate (kg/ha)					
	37.5	50	62.5	37.5	50	62.5
OL10	2725	2388	2235	2965	2744	2520
OL 11	3052	2596	2495	3247	2963	2661
LSD (P<0.05)	NS					

NS: Non-significant

The effect of seed rate on oat biological yield was consistent in all the four cropping seasons. Biological yield in the highest seed rate treatment was consecutively greater than in the lowest seed rate treatment but the differences remained statistically non-significant. The narrow row spacing and increased plant density with higher seed rates, resulted in increased above ground biomass accumulation (Lafond *et al*., 2013; Liu *et al*., 2016; May *et al*., 2020) but decreased the crop photosynthetic assimilation and thus reduced yield as observed in this study. Oat seed yield was significantly influenced by the oat varieties during 2017-18 and 2018-19. Across the cropping seasons, and different treatments, the oat variety OL 11 yielded approximately 9.2% higher than OL 10 variety. Likewise, the biological yield of OL 11 was significantly higher than OL 10 on an average of four cropping seasons.

The effect of row spacing on harvest index was significant during 2016-17 and 2018-19, while the differences were statistically similar during 2017-18 and 2019-20. Higher harvest index was recorded in oat sown in 30 cm row spacing than in the 20 cm row spacing. The effect of seed rate on harvest index was consistent in all the cropping seasons. Higher harvest index was recorded with 37.5 kg/ha seed rate than the other higher seed rates used. Harvest index was found to be not affected by the oat varieties except during 2016-17. The partitioning of dry matter or photo assimilates towards the sink or the reproductive organs could be judged from the harvest index of the crop (Reynolds and Langridge, 2016). Hence, the higher HI observed in 30 cm row spacing and with 37.5 kg/ha seed rate during the four cropping seasons indicated better dry matter partitioning towards the developing seeds in these treatments. HI was bound to vary under different crop management practices (Ainsworth *et al*., 2012) and increased dry matter partitioning was a fundamental response to row spacing and plant density as observed in this study. The biological yield of the crop increased at 20 cm row spacing and with higher seed rate *i.e.* 50 and 62.5 kg/ha which could have been due to increased plant height as observed in this study. In narrower row spacing and as planting density increased, the photosynthetic characteristics and photosynthates assimilation towards the sink decreased and thus the HI decreased. With regard to economics of the system, benefit: cost ratio was positively influenced by the oat varieties and seed rate, however there was non-significant differences in benefit: cost ratio due to row spacing. Highest benefit: cost ratio was obtained with variety OL 11 and seed rate of 37.5 kg/ha.

Conclusion

This study showed that fodder oat varieties responded favourably to wide row spacing of 30 cm and seed rate of 37.5 kg/ha for producing desirable seed yields. Although both the fodder oat varieties behaved similarly but still the seed yield of OL 11 was more than OL 10.

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