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The combined effect of varieties, sowing techniques and seed rate for oat (*Avena sativa* L.) seed production

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Abstract
The experiment was conducted at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) during *Rabi* season of 2018-19 and 2019-20 to study "The combined effect of varieties, sowing techniques and seed rate on oat seed production" was carried out in strip split plot design with three replications in clay (*Vertisols*) soil, locally known as Kanhar. In this experiment two varieties: V_1 - JHO-822 and V_2 - JO-1 was allotted in vertical strips further two sowing methods: M_1 -Line sowing and M_2-Broadcasting method was taken in horizontal strip and in sub plots three seed rates: S_1-80 kg ha^{-1}, S_2- 90 kg ha^{-1} and S_3-100 kg ha^{-1} was randomized. Recommended dose of fertilizer of 120:60:40 N: P_2O_5: K_2O ha^{-1} was applied. Nitrogen was applied in two splits, 50 percent at basal and 50 percent after first cut. Varieties, sowing methods and seed rate had significant effect (p<0.05) on the yield parameters. Two years pooled data analysis results revealed that significantly higher seed yield was recorded under the variety JHO-822 (30.68 q ha^{-1}), when crop was sown inline sowing (30.75 q ha^{-1}) with 90 kg ha^{-1} seed rate (31.47 q ha^{-1}). Statistically no significant difference was observed among all the interaction effects.

Keywords: Sowing method, seed rate, varieties, seed yield, harvest index

Introduction
The well-known winter cereal crop oat (*Avena sativa* L.), sometimes referred to as Javi, is farmed all over the world for both feed and seed. Oats can be used to make nutritious food for humans as well as high-quality feed and fodder for livestock. Oats are a crop that can be grown successfully in areas with limited irrigation infrastructure. Farmers often take one cut for grazing and then leave the crop to produce seeds. It requires cool and moist weather for germination. This crop is quick growing with good regeneration capacity. The annual global production of oat is about 22.91 million tonnes from an area on 9.46 million ha around the world, with a yield of 2.42 metric tonnes ha^{-1} (Anonymous 2019) [1]. Cultivated fodder in India is limited to 4.9 percent of total cropped land (Kumar *et al*. 2012) [4]. In India oat is grown on 100,000 hectares of area with productivity of 35-40 tonnes of green fodder per hectare.
Oat is low in saturated fat, and very low in cholesterol and sodium. It contains 10-12% crude protein, 30-32% digestible crude fiber, and has highest dry matter digestibility of 60-70% (Sharma *et al.* 1999) [9]. Multiple cuts are usually made, and then the crop can be preserved in whole or in part for seed (Peterson *et al.* 2005) [7]. The state's livestock population is estimated to be 158.72 lakhs, including 99.84 lakhs of cattle, 11.75 lakhs of buffaloes, and 47.13 lakhs of other animals like as sheep, goats, horses, and other species (Anonymous, 2019) [1].
Although the land and climate of Chhattisgarh are ideal for growing oats. As a result, in the proposed study, we will assess the seed production technology for the state of Chhattisgarh using seed rate manipulation and sowing method procedures. This research will help farmers, state seed producers, and seed producers grow self-sufficient in fodder oat seed. Chhattisgarh is currently unable to meet its green fodder and seed needs. Lack of sufficient supplies of high-quality fodder seed and a broken supply chain for fodder seed are the main contributors to the state's fodder crisis.
According to Ayub *et al.* (2003) [2], the influence of 80, and 120 kg N ha^{-1} and 75, 100, and 120 kg seed rate ha^{-1} on oat fodder yield quality, nitrogen at 120 kg ha^{-1} and seed rate 120 kg ha^{-1} were the best combination for generating higher green fodder productivity of oats. Planting methods that balance inter plant completeness have an impact on plant growth and development. It regulates how plants spread out across the field and directly affects cosmic radiation, interception, evaporation, and the effectiveness of agricultural water use. Oats sown in lines produced more forage and had a better benefit-cost ratio than those sown in rows,

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Oat is low in saturated fat, and very low in cholesterol and sodium. It contains 10-12% crude protein, 30-32% digestible crude fiber, and has highest dry matter digestibility of 60-70% (Sharma *et al.* 1999) [9]. Multiple cuts are usually made, and then the crop can be preserved in whole or in part for seed (Peterson *et al.* 2005) [7]. The state's livestock population is estimated to be 158.72 lakhs, including 99.84 lakhs of cattle, 11.75 lakhs of buffaloes, and 47.13 lakhs of other animals like as sheep, goats, horses, and other species (Anonymous, 2019) [1]. Although the land and climate of Chhattisgarh are ideal for growing oats. As a result, in the proposed study, we will assess the seed production technology for the state of Chhattisgarh using seed rate manipulation and sowing method procedures. This research will help farmers, state seed producers, and seed producers grow self-sufficient in fodder oat seed. Chhattisgarh is currently unable to meet its green fodder and seed needs. Lack of sufficient supplies of high-quality fodder seed and a broken supply chain for fodder seed are the main contributors to the state's fodder crisis.

According to Ayub *et al.* (2003) [2], the influence of 80, and 120 kg N ha^{-1} and 75, 100, and 120 kg seed rate ha^{-1} on oat fodder yield quality, nitrogen at 120 kg ha^{-1} and seed rate 120 kg ha^{-1} were the best combination for generating higher green fodder productivity of oats. Planting methods that balance inter plant completeness have an impact on plant growth and development. It regulates how plants spread out across the field and directly affects cosmic radiation, interception, evaporation, and the effectiveness of agricultural water use. Oats sown in lines produced more forage and had a better benefit-cost ratio than those sown in rows, according to Sharma *et al.* (2001) [11]. The biggest obstacle to raising fodder yield is the farmer's lack of access to superior cultivars high-quality seeds. Therefore, agronomic techniques that raise the caliber of seed production are essential. Inhibiting seed formation by harvesting foliage during the vegetative stage prevents the production of seeds for fodder (Patel *et al.*, 2011) [6].

Material and Methods

A field experiment was carried out at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) during *Rabi* season of 2018-19 and 2019-20. The experimental field soil has a clay texture (*Vertisols*) sometimes referred to as locally Kanhar. The experiments, sowing techniques and seed rates on oat varieties for seed production were conducted during two consecutive *Rabi* seasons of 2018-19 and 2019-20. The soil was neutral (pH 7.0 -7.3) in reaction with medium in fertility having 0.66 - 0.69% soil organic carbon, low nitrogen (250 - 252 kg ha^{-1}), low phosphorus (16 - 18 kg ha^{-1}), and high potassium (320.31 - 324.42 kg ha^{-1}). Three replications in a strip split plot design. In this experiment, two varieties V_1- JHO-822 and V_2- JO-1and two sowing techniques were each given a vertical strip of land. In horizontal strips M_1-line sowing and M_2-broadcast methods were used, and in sub-plots three seed rates S_1- 80 kg ha^{-1}, S_2- 90 kg ha^{-1}, and S_3-100 kg ha^{-1} were randomized. Manual sowing was done at a depth of 5 cm with rows spaced 30 cm apart, and the required fertilizer concentration of 120:60:40 N: P_2O5: K_2O ha-^{1} was used 50 percent of the nitrogen was administered at the base and 50 percent after the first cut.

Results and Discussion

Number of panicles (m^{-2})

Data on the number of panicles (m^{-2}) was significantly variety, sowing methods and seed rates are presented in Table 1.

Among the varieties, significantly more panicles were counted under the variety JHO-822 than JO-1 on average across the years. As regard sowing method, Comparing the broadcast method to the mean throughout the years, the crop sown in line produced substantially more panicles. According to this notion, line sowing technique resulted in greater nutrient, water, and sun radiation absorption, which increased the metabolic translocation of plants reproductive organs. Sharma and Malik (1993) [10] reported similar outcomes.

The data regarding to different seed rates, significantly highest number of panicles was noted in 90 kg ha^{-1} seed rate as compare to other seed rate but it was at par with 100 kg ha^{-1} seed rate during mean over the years. It might be plots with an ideal plant population have better root dispersion, a better environment for growth and development, and higher water and nutrient uptake than plots with a dense population. These results are findings of Jena and Behera (1998) [3]. The effect of cultivars, sowing techniques, and seed rate on the number of panicles was determined to be non-significant for both the individual years and the average throughout the years.

Panicle length (cm)

The data indicated to panicle length was influenced significantly variety, sowing method and seed rates, during 2018-19 and 2019-20 are presented in (Table 1).

Regarding the variety, the variety JHO-822 (37.74 cm) had longer panicles than JO-1 on average across the years. As regard the sowing method, significantly longer panicle length was recorded when crop was sown in line (36.95 cm) as compare to broadcast method during mean over the years. As a result of better light interception and air circulation around the lower canopies, which likely carried their conductive effect of photosynthetic activity of the crop to a remarkable degree and helped in increasing panicle length, the longer panicle length may be caused by more or less equal distance between the plants. The similar results have been reported by Sharma and Malik (1993) [10] and Panda *et al.* (1996) [5]. When compared to other seed rates, crop sown at 90 kg ha^{-1} (37.97 cm) had much longer panicles, although the average across the years showed that it was at par with 100 kg ha^{-1} seed rate. The interaction effect between varieties, sowing methods and seed rate was found non-significant for panicle length during both the experimental years.

Panicle weight (g)

A perusal data presented in Table during 2018-19 and 2019-20 revealed that influence of varieties, sowing methods and seed rate on oat.

Among the varieties, maximum panicle weight was recorded higher under the variety JHO-822 (4.19 g) than JO-1 during

the mean over the years. Regarding sowing techniques, higher panicle weight was observed when the crop was sown in line (4.03 g) as compared to broadcast. Among the seed rates, in comparison to other seeding rates, the maximum panicle weight was much higher when it was sown at a rate of 90 kg ha^{-1} (4.65 g), but it was at par with the 100 kg ha^{-1} seed rate for both years, and the mean over the years. Regarding the number of panicle weight for both the years and the over mean data, the interaction effects among varieties, sowing techniques, and seed rate was to be non-significant.

Filled grains panicle^{-1}

Data regarding filled grains per panicle as influenced by varieties, sowing methods and seed rates are given in Table 2

Table 1: No. of panicle (m^{-2}), panicle length (cm) and panicle weight (g) of fodder oat as influenced by varieties, sowing methods and seed rate

Treatment		No. of panicle (m^{-2})			Panicle length (cm)			Panicle weight (g)		
		2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
A. Varieties										
V_1	JHO-822	377.71	373.14	375.43	38.45	37.03	37.74	4.91	3.47	4.19
V_2	JO-1	357.80	352.98	355.39	35.14	33.42	34.28	3.68	2.86	3.27
S.Em±		1.97	1.74	1.85	0.44	0.33	0.37	0.16	0.09	0.08
CD (P=0.05)		11.99	10.57	11.27	2.68	2.00	2.28	0.94	0.58	0.51
B. Sowing method										
M_1	Line Sowing	383.32	380.83	382.08	37.59	36.30	36.95	4.48	3.59	4.03
M_2	Broadcasting	352.19	345.30	348.74	35.99	34.15	35.07	4.11	2.74	3.42
S.Em±		4.22	2.92	3.30	0.25	0.28	0.23	0.06	0.12	0.08
CD (P=0.05)		25.68	17.79	20.11	1.54	1.72	1.41	0.36	0.75	0.47
C. Seed rates										
S_1	80 kg ha^{-1}	340.55	331.34	335.95	34.07	33.51	33.79	3.47	2.32	2.89
S_2	90 kg ha^{-1}	389.13	386.17	387.65	38.96	36.98	37.97	5.28	4.02	4.65
S_3	100 kg ha^{-1}	373.59	371.68	372.63	37.36	35.19	37.10	4.13	3.16	3.65
S.Em±		5.71	5.63	5.51	1.14	1.03	0.31	0.52	0.32	0.42
CD (P=0.05)		17.12	16.88	16.53	3.43	3.08	0.99	1.55	0.95	1.25
Interaction V X SM X SR		NS	NS	NS	NS	NS	NS	NS	NS	NS

Among the varieties, Maximum fill grains was recorded under the variety JHO-822 (55.80 and 53.20 in 2018–19 and 2019–20, respectively) than JO-1 for both the years and mean values. Among the sowing method, When crop was sown in line (52.73 and 48.49 in 2018–19 and 2019–20, respectively), maximum filled grains were considerably higher than when crop was broadcast during both years due to broadcasting among closely spaced plants increased competition for resources including light, water, and nutrients, which led to less full grain growth in panicles.

As regard the seed rate, significantly higher filled grains were recorded when crop was sown in seeding rate of 90 kg ha^{-1} (55.95 and 52.83 in 2018-19 and 2019-20) but it was at par with 100 kg ha^{-1} seed rate during both the years and mean over the years. The smaller number of filled grains with higher seed rate might be due to less number of panicles. These finding are similar results with Jena and Behera (1998) [3] and Prasad *et al*. (1991) [8]. The interaction impact between varieties, sowing techniques, and seed rate was not significant.

Unfilled grains panicle^{-1}

Data regarding Unfilled grains panicle^{-1} by varieties, sowing methods and seed rates are presented in Table 2

Among the varieties, Maximum chaffy grains was recorded under the variety JO-1as compare to JHO-822 during both the years and mean values. Among the sowing methods, significantly maximum chaffy grains were recorded when crop was sown in broadcast method (4.40) over to line sowing methods during mean over the years. This may be properly positioned plants have a higher chance of receiving nutrition and moisture than plants that are distributed unevenly, which has an impact on the formation of chaffy grains in the oat crop. Among the seed rate, significantly maximum chaffy grains were recorded when crop was sown in 80 kg ha^{-1} (4.55) but it was at par with 100 kg ha^{-1} rate of seeding during mean over the years. The interaction effect between variety, sowing methods and seed rate was found non-significant during both the years and mean over the years.

100 seed weight (g)

Data regarding 100 seed weight (g) as influenced by varieties, methods of sowing and seed rates are given in Table 2.

Among the varieties, significantly maximum 100 seed weight was recorded under the JHO-822 (5.85 g) as compared to JO-1 during mean over the years. Significantly maximum 100 seed weight was obtained while crop was sown in line (5.48 g) as compared to broadcast method during both experimental years and over the years. The improved growth development of the crop, which led to increased nutrient uptake and better grain nutrition, resulted in bolder size grains, which in turn led to a higher 100 seed weight, was most likely the cause of the higher 100 seed weight under line sowing. The similar results had been reported by Panda *et al*. (1996) [5].

Among the seed rate, significantly maximum 100 seed weight was recorded when crop was sown in 90 kg ha^{-1} (5.78 g) as compare to other seed rate during mean over the years. No significant was found of the interaction between variety, sowing methods and seed rate with respect during 2018-19 and 2019-20 and mean data.

Seed set (%)

The data on seed set percent as influenced by varieties, sowing methods and seed rate are presented in Table 2.

Among the varieties, significantly maximum seed set percent was recorded in JHO-822(94.42%) as compare to JO-1(89.52%) during both the years and mean over the years. Among the sowing methods, significantly maximum seed set percent was recorded when crop was sown in line (92.81%) as compare to broadcast methods during both the years and mean over the years. As regard the seed rate, significantly maximum seed set percent was recorded when crop was sown in 90 kg ha^{-1} (94.26%) as compared to other seed rates during

both the experimental years and mean over the years. The interaction effect between varieties, sowing methods and seed rate was found non-significant for seed set percent during both the years and mean over the years.

Seed yield (q ha^{-1})

The data on effects of varieties, sowing methods and seed rates on seed yield are presented in table 3 during both of years and mean.

Table 2: Filled grain panicle^{-1}, unfilled grain panicle^{-1}, 100 seed weight (g) and seed set % of fodder oat as influenced by varieties, sowing methods and seed rates

Treatment		Filled grain panicle^{-1}			Unfilled grain panicle^{-1}			100 seed weight (g)			Seed set %		
		2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
A. Varieties													
V_1	JHO-822	55.80	53.32	54.56	2.32	3.89	3.10	6.18	5.52	5.85	95.90	92.93	94.42
V_2	JO-1	44.66	41.57	43.11	4.09	5.65	4.87	5.23	4.79	5.01	91.26	87.77	89.52
S.Em±		1.21	1.08	1.12	0.29	0.17	0.14	0.16	0.22	0.19	0.71	0.23	0.47
CD(P=0.05)		7.34	6.55	6.81	1.74	1.03	0.82	0.96	1.35	1.16	4.31	1.41	2.83
B. Sowing method													
M_1	Line Sowing	52.73	48.59	50.66	2.94	4.21	3.58	5.79	5.17	5.48	94.35	91.27	92.81
M_2	Broadcasting	47.72	46.30	47.01	3.47	5.33	4.40	5.61	5.14	5.37	92.82	89.43	91.12
S.Em±		0.47	0.20	0.32	0.02	0.04	0.03	0.08	0.02	0.05	0.07	0.11	0.04
CD(P=0.05)		2.86	1.21	1.92	0.13	0.26	0.19	0.48	0.13	0.27	0.43	0.69	0.23
C. Seed rates													
S_1	80 kg ha-^{1}	42.72	40.18	41.45	3.70	5.39	4.55	5.41	4.79	5.10	91.61	87.98	89.80
S_2	90 kg ha^{-1}	55.95	52.83	54.39	2.32	3.96	3.14	6.06	5.51	5.78	95.86	92.67	94.26
S_3	100 kg ha^{-1}	52.02	49.32	50.67	3.59	4.96	4.28	5.63	5.17	5.40	93.28	90.40	91.84
S.Em±		1.34	1.31	1.32	0.13	0.18	0.14	0.06	0.07	0.03	0.26	0.39	0.16
CD(P=0.05)		4.01	3.93	3.97	0.38	0.54	0.42	0.17	0.21	0.09	0.78	1.16	0.47
Interaction V X SM X SR		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Among the varieties, significantly maximum seed yield was recorded under the variety JHO - 822 (30.68 q ha^{-1}) as compared to JO-1 during both the years and mean over the years. The mean seed yield was 30.68 q ha^{-1} which was 11.32% higher in variety JHO-822 over JO-1. As regard to sowing methods, significantly superior seed yield was recorded in line sowing (30.75 q ha^{-1}) over broadcast method during both the years and mean over the years. In line sowing method mean seed yield 11.85% higher than broadcast. Greater photosynthesis results in higher values for growth parameters plant height, dry matter, number of tillers, number of panicles, length of panicle, and 100 seed weight, which in turn causes higher seed yield and straw production. Reduced seed and straw yield under broadcast the reason for the lower seed and straw yield could be related to increasing plant competition, which reduced sun radiation, water, and nutrients for individual plants. These resulted the findings of Prasad *et al.* (1991) [8], Sharma and Malik (1993) [10].

Among the seed rate, significantly maximum seed yield was reported when crop was sown in 90 kg ha^{-1} (26.53 q ha^{-1}) as compared to other seed rates but it was at par with 100 kg ha^{-1} (29.35 q ha^{-1}) during both the years and mean over the years. In comparison to dense populations, optimal plant populations higher chances for nutrients, air, light, moisture, and other growth components. Interaction effect between varieties, sowing methods and seed rate on seed yield was found non-significant during both the yeas and mean over the years.

Straw yield (q ha^{-1})

The data on effect of different varieties, sowing methods and seed rate on straw yield q ha^{-1} are presented in Table 3.

Among the varieties, significantly higher straw yield was recorded under the JHO-822 (74.23 q ha^{-1}) as compare to JO-1 (69.18 q ha^{-1}) during mean over the years. The mean straw yield was 74.23 q ha^{-1} which was 7.29% higher in variety JHO-822 over JO-1. As regard the sowing methods, significantly maximum straw yield was recorded when crop was sown in line sowing (74.33 q ha^{-1}) significantly over to broadcast (69.08 q ha^{-1}) during both the years and mean data. Oat plants under line sowing utilized the interrow space more effectively, which supported improved crop growth and increased straw yield.

Table 3: Seed yield (q ha^{-1}), Straw yield (q ha^{-1}) and Harvest index of fodder oat as influenced by varieties, sowing methods and seed rates

Treatment		Seed yield (q ha^{-1})			Straw yield (q ha^{-1})			Harvest index		
		2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
A. Varieties										
V_1	JHO-822	33.11	28.25	30.68	75.67	72.78	74.23	30.43	28.03	29.23
V_2	JO-1	29.06	26.06	27.56	71.56	66.79	69.18	28.89	27.93	28.41
S.Em±		0.44	0.32	0.08	0.51	0.97	0.40	0.46	0.39	0.09
CD(P=0.05)		2.70	1.95	0.46	3.11	5.90	2.43	NS	NS	0.58
B. Sowing methods										
M_1	Line Sowing	32.44	29.06	30.75	76.50	72.16	74.33	29.69	28.66	29.18
M_2	Broadcasting	29.73	25.25	27.49	70.73	67.42	69.08	29.63	27.30	28.46
S.Em±		0.40	0.26	0.08	0.81	0.19	0.36	0.43	0.27	0.15
CD(P=0.05)		2.45	1.58	0.48	4.96	1.16	2.16	NS	NS	NS
C. Seed rates										
S_1	80 kg ha^{-1}	28.35	24.72	26.53	69.58	64.78	67.18	28.98	27.56	28.27
S_2	90 kg ha^{-1}	33.46	29.49	31.47	76.74	73.69	75.21	30.31	28.63	29.47
S_3	100 kg ha^{-1}	31.44	27.26	29.35	74.53	70.89	72.71	29.68	27.75	28.72
S.Em±		0.83	1.22	1.00	0.96	1.11	0.98	0.40	0.65	0.45
CD(P=0.05)		2.49	3.66	2.99	2.89	3.33	2.95	NS	NS	NS
Interaction V X SM X SR		NS	NS	NS	NS	NS	NS	NS	NS	NS

Among the seed rate, significantly maximum straw yield was recorded when crop was sown in 90 kg ha^{-1} (75.21 q ha^{-1}) as compared to other seed rates but it was at par with 100 kg ha^{-1} seed rate during both the experimental years and mean over the years. Interaction effect of varieties, sowing methods and seed rate on straw yield was found non-significant during both the years and mean over the years.

Harvest index

Data pertaining to harvest index as influenced by different varieties, sowing methods and seed rates are presented in Table 3.

Among the varieties, harvest index was found non-significant during both the years except mean data. Maximum harvest index was recorded under the variety JHO-822 as compared to JO-1 during both the years and mean over the years.

Among the sowing method, harvest index was found non-significant. maximum harvest index was recorded when crop was sown in lines as compared to broadcast during both the years and mean over the years. The increased harvest index under line planting could be attributable to more photosynthetic diversion toward the reproductive organ rather than the vegetative component, *i.e.*, from source to sink. These results findings similar with Sharma and Malik (1993) [10]. As regard the seed rates, harvest index was found non-significant. higher harvest index was recorded when crop was sown in 90 kg ha^{-1} as compared to other seed rates during both the years and mean over the years. Interaction effect of varieties, sowing methods and seed rate on harvest index was found non-significant during both the experimental years and mean data. Significantly highest yield attributes and seed yield was recorded under the combination of JHO-822 variety, when crop was sown in line sowing and seed rate was taken 90 kg ha^{-1}

Conclusion

Significantly highest yield attributes and seed yield was recorded under the combination of JHO-822 variety when crop was sown in line sowing and seed rate was taken 90 kg ha^{-1}

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