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A high yielding Fennel (*Foeniculum vulgare*) variety, Ajmer Fennel-2 (AF-2) for better resistance, quality with higher essential oil content to grow in India

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Abstract

Fennel is medicinally and economically important crop of India. This crop is the rich source of antioxidants and used in many medicines to cure diseases. In spite of already available varieties there is a need for development of high yielding, *Ramularia* blight tolerant variety with higher essential oil content. A high yielding, *Ramularia* blight tolerant variety, AF-2 (Ajmer Fennel-2) has been released and notified by the CVRC (Notified vide S.O.216 (E)16.01.2018) for commercial cultivation under timely sown, recommended POP for all fennel growing areas of India. AF-2 has an average yield of 17.9 q ha⁻¹ which is 10.62% and 12.94% higher as compared to national checks, RF-205 and RF-101, respectively. AF-2 is moderately resistant to *Ramularia* blight disease and its seed contains 1.9% essential oil which was 18.5 % and 11.7 % higher than RF-205 and RF-101, respectively. Fertilizer requirement was 5-10 t ha⁻¹ FYM and 90 kg N₂ and 40 kg P₂O₅ & 30 kg K₂O ha⁻¹. The variety will contribute to increase fennel production and will alleviate the socio-economic status of its farmers.

Keywords: Fennel, Ajmer Fennel-2, yield, disease resistance, quality, essential oil

Introduction

Fennel (*Foeniculum vulgare*), is a highly aromatic and flavorful herb with culinary and medicinal uses from the family Apiaceae. It is an annual, biennial or perennial herb, native to Mediterranean region and grown throughout Asia, North America and Europe. A cosmopolitan species, Fennel is commonly cultivated from the plains to 2000 m and has a wide distribution. It was grown by romans for its aromatic fruits and edible fleshy gardens (Abubacker, 2011). Widely cultivated in India, Argentina, China, Indonesia, Russia, Japan and Pakistan (Volak and Stodola, 1998). This crop is the rich source of antioxidants and used in many medicines to cure diseases (Oktay,

2003, Lucinewton, 2005, Bruyas-Bertholon, 2012). Studies have been conducted on antioxidant potential of fennel (Choudhary, 2017), DNA isolation protocol (Choudhary, 2015), induced variability (Verma, 2018), radiation effect (Verma, 2017), lethal dose fixation morphological and molecular variability in mutant lines (Sharma 2020), molecular diversity analysis (Choudhary, 2018). Rajasthan is one of the major fennel growing states of India cultivating this crop since ages, but the biotic and abiotic stresses are effecting its growth and yield. A variety with more yield and resistance to diseases and pests, with higher essential oil content can be a boon to the fennel growers. Looking to the problems of the farmers an experiment was designed to develop a superior variety for yield, resistance and quality of fennel. Fennel producers have been advocated to adopt the recently released high yielding *Ramularia* blight resistant and superior quality fennel varieties to counter the significant yield losses. In light of the likelihood of blight incidence, researchers advocate the farmers to cultivate the improved and/or recently released fennel varieties that are resistant/tolerant to multiple biotic and abiotic stresses including blight to counter the significant yield and profit loss.

Materials and methods

Yield and quality superiority and adaptability: The selected lines were screened and evaluated before national yield evaluation and hence only resistant genotypes with higher yield were promoted to evaluation in the coordinated trials. In multi-location testing during the process of evaluation, yield and blight responses at each location were recorded and the proposed fennel variety AF-2 gave 17.9 q ha⁻¹ average seed yield, which is 10.62% and 12.94% higher as compared to national checks, RF-205 and RF-101, respectively in 27 trials conducted at different locations across the country (Table 1 and 1a). The proposed variety AF-2 gave 17.5 q ha⁻¹ average seed yield which is 8.55% and 8.60% higher than national checks, RF-205 and RF-101, respectively in coordinated trials (Table 2 and 2a). AF-2 is found superior in quality traits (Table 3, 6 and 6a)

Distinguishing morphological characteristics: Medium plant height, dense foliage (at fully bloom leaf

stage), king umbel base leaf is straight, Semi erect foliage attitude, king umbel leaf have petiole and short 1st inter-node (Table 7)

Results and discussion

Performance in agronomical evaluation: Suitability for early or late sown conditions, seed rate, were examined and found that mentioned genotypes are suitable for normal sown conditions. 15th October is most suitable date for sowing. Seed rate and spacing: 8-10 kg ha⁻¹ with 50cm line to line and 25 cm plant to plant distance. 5-6 irrigations are sufficient depending on soil type and climatic conditions. Yield was 8-10 kg ha⁻¹ with 50cm line to line and 25 cm plant to plant distance. Fertilizer requirement was 5-10 t ha⁻¹ FYM and 90 kg N₂, 40 kg P₂O₅ and 30 kg K₂O ha⁻¹, good quality grain with higher essential oil was obtained; total yield was 1790 kg ha⁻¹ (Table 5).

Resistance to disease and pests: AF-2 is moderately resistant to *Ramularia* blight disease (Table 4a and 4b). Fennel is mostly attacked by aphids whereas the proposed variety is less susceptible as compared to other released variety as observed in the field.

Seed characteristics and quality: Its seed contain 1.9% essential oil which was 18.5 and 11.7 % higher than RF-205 and RF-101, respectively. Its essential oil contain 57.5% Anethol + Estyragol which is 22.4% higher than RF-205 (Table 6a and 6b).

Conclusion

Development of variety: To effectively monitor coordinated trials, multidisciplinary teams were constituted to monitor trial-conducting centers across fennel growing areas. Monitoring and evaluation are carried out for examining the scientific conduction of trials and performance of test genotypes. The collective decisions of the monitoring team members on the acceptance/rejection of a trial are considered for monitoring reports. Based on three-year performance at multiple locations, the best performing test entry was identified and proposed in XXVII workshop of AICRP on spices, Calicut. Subsequently, the identified variety is released vide the Notified vide S.O.216(E)16.01.2018

Conflicts of Interest : The authors declare no conflicts of interest.

Table1: Summary of performance of proposed fennel variety in station and coordinated trials at different locations across the country for seed yield (kg ha⁻¹)

Particulars	Proposed entry (AF-2)	National check RF-205	National check RF-101
Years of testing	2010-11 to 2014-15	2012-13 to 2014-15	2010-11 to 2014-15
Total yield over the locations/years	48340.27	404692.92	42800.44
No of locations/years	27	26	27
Mean	1790.4	1618.5	1585.2
% increase over National check RF-205			10.62
% increase over National check RF-101			12.94

Table 1a:Seed yield (kg ha⁻¹) of fennel varieties in station and coordinated trials at different locations across the country

Year	Trial/Location	AF-2 (AJ-FNL-2)	RF-205 (National Check)	RF-101 (National Check)
2010-11	SFTNRCSS, Ajmer	2000.0	NT	1252.8
2011-12	SFT NRCSS, Ajmer	2416.0	NT	1101.7
2012-13	SFT NRCSS, Ajmer	4349.0	1342.0	1562.0
2014-15	CVT NRCSS, Ajmer	1303.0	1862.5	1630.7
2012-13	CVT Hisar	1760.0	1692.4	1685.5
2013-14		1785.0	2782.0	2804.0
2014-15		1832.4	1198.1	1537.0
2012-13	CVT Jobner	3322.0	1892.5	1735.1
2013-14		1730.0	1205.0	875.0
2014-15		2068.5	1220.0	1189.0
2012-13	CVT Jagudan	1285.0	1202.0	1212.0
2013-14		1290.0	1093.0	1127.0
2014-15		1219.0	1100.0	1097.0
2012-13	CVT Kumarkanj	1336.	1048.0	1041.0
2013-14		1288.0	1971.0	3504.0
2014-15		1236.0	1424.0	1319.0
2012-13	CVT Jabalpur	1618.0	1424.0	615.0
2014-15		1233.0	1880.0	1050.0
2012-13	CVT Dholi	1023.0	592.5	1314.0
2013-14		1037.0	662.0	1268.0
2014-15		1333.3	976.0	1527.8
2012-13	CVT Pantnagar	1898.0	2733.0	2037.0
2013-14		1736.1	2430.5	2592.5
2014-15		1745.1	2541.1	2254.7
2012-13	CVT Navasari	1300.0	1617.0	1450.0
2013-14		2627.3	2425.9	2013.8
2014-15		2569.4	2148.1	2004.6
	Mean	1790.38	1618.517	1585.201
	% increase over National checkRF-205		10.62	
	% increase over National checkRF-101			12.94

Table 2. Average Seed yield (kg ha⁻¹) of proposed fennel variety with checks in CVTs

Particular	Proposed entry (AF-2)	National check RF-205	National check RF-101
Years of testing	2012-15	2012-15	2012-15
Total yield over the locations /year	43924.27	40462.92	40445.94
No of locations /year	25	25	25
Mean	1757.0	1618.5	1617.8
% increase over National checkRF-205			8.55
% increase over National checkRF-101			8.60

Table 3. Average performance of fennel varieties tested in coordinated trial among the 12 entries for seed yield (kg ha⁻¹).

Entries	Code	Average seed yield (kg ha ⁻¹)	% higher than National check RF-205	% higher than National check RF-101	Rank
AJ-FNL-2	FNL-47	1757.0	8.55	8.6	1
AF 05-1-3	FNL-48	1667.5	3.03	3.07	2
UF-157	FNL-49	1534.4	-5.19	-5.15	9
UF-278	FNL-50	1602.5	-0.99	-0.95	6
HF-119	FNL-51	1608.5	-0.62	-0.58	5
HF-147	FNL-52	1538.9	-4.92	-4.88	8
NDF-45	FNL-53	1478.4	-8.66	-8.62	11
NDF-46	FNL-54	1448.1	-10.53	-10.49	12
JF-671-1	FNL-55	1488.1	-8.06	-8.02	10
JF-674-1	FNL-56	1558.2	-3.73	-3.69	7
RF-205 Ch.		1618.5	0	0.04	3
RF-101 Ch.		1617.8	0.04	0	4

Table 4. Performance of proposed genotypes for *Ramularia* blight disease reaction in station trials at NRCSS Ajmer during 2012-13 and 2014-15

S.No.	Name of entries	2012 -13	2014 -15	Average
1	AJ-FNL -2 (AF -2)(Proposed entry)	24	20	22
2	RF -125	69	48	45.5
3	RF -101	65	42	46.5

Table 4a. Performance of proposed genotypes for *Ramularia* blight disease reaction in station trials at NRCSS Ajmer during 2012-13 and 2014-15

S.No.	Name of entries	2012-13	2014-15	Average
1	AJ-FNL-2 (AF-2)(Proposed entry)	18	20	23.5
2	RF-205	44	38	41
3	RF-101	46.7	36	41.35

Table 3. Quality attributes of the proposed variety ACel-2 tested at NRCSS, Ajmer during 2010-11 and 2016-17

Entries	Code	Hisar			Jobner			Jagudan			Kumarganj		
		2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15
AJ-FNL-2	FNL-47	1760	1785	1832.4	3322	1730	2068.52	1285	1290	1219	1336	1288	1236
AF 05-1-3	FNL-48	1866	1859.2	1868.5	2652	1722.22	2279.63	1156	1324	877	1249	1249	1187
UF-157	FNL-49	1315	1574.5	1626.3	3426	1433.33	2357.41	1054	1277	1378	1023	1062	999
UF-278	FNL-50	1396	1531.4	1586.2	2859	1370.37	2359.26	857	953	1068	1145	1152	1090
HF-119	FNL-51	1883	1865.5	1652.4	3085	929.63	2374.07	1104	1241	969	1076	1083	1020
HF-147	FNL-52	1985	1742.6	1695.8	2830	1037.04	1825.93	865	1188	825	1180	1145	1083
NDF-45	FNL-53	1549	2062.3	2195.4	2456	948.15	1707.41	710	1042	820	1065	1270	1208
NDF-46	FNL-54	1567	2176.6	2286.6	2074	1122.22	1751.85	692	1038	765	1215	1254	1194
JF-671-1	FNL-55	1344	1599.8	1482.5	2419	1042.59	2085.19	1299	1340	1549	1082	1103	1041
JF-674-1	FNL-56	1431	1506.5	1627.4	2644	1103.7	2231.48	1221	1308	1748	1215	1194	1131
RF-205 Ch.		1342	1862.5	1692.4	2782	1198.15	1892.5	1205	1220	1202	1093	1100	1048
RF-101 Ch.		1562	1630.7	1685.5	2804	1537.04	1735.1	875	1189	1212	1127	1097	1041
CD (p=0.05)		62	55.8	55.2	440	190.1	343.03	158	183		134	59	
CV (%)		7.24	2.9	1.9	9.46	8.72	9..95	9.26	9.11		4.28	3.01	

Table 2a (contd.): Seed yield (kg ha⁻¹) of fennel varieties in coordinated trial at different location across the country during 2012-13 to 2014-15

Entries	Code	Ajmer			Jabalpur			Dholi		
		2012-13	2014-15	2012-13	2012-13	2013-14	2014-15	2012-13	2013-14	2014-15
AJ-FNL-2	FNL-47	4349	1303.0	1618	888	1233	1023	1037	1333.3	
AF 05-1-3	FNL-48	2124	1751.7	1549	678	1468	1259	1236.1	1541.7	
UF-157	FNL-49	1929	1352.0	855	277	868	482	476.9	773.2	
UF-278	FNL-50	2278	1581.3	1090	666	948	1597	1393.5	1699.1	
HF-119	FNL-51	2111	1470.3	643	543	752	1144	1120.4	1425.9	
HF-147	FNL-52	2041	1388.3	619	641	620	1380	1363.7	1662.0	
NDF-45	FNL-53	2183	1339.8	416	321	810	1232	1189.8	1476.9	
NDF-46	FNL-54	1797	1390.3	347	310	865	1273	1240.7	1527.8	
JF-671-1	FNL-55	1931	1371.3	744	440	898	866	879.6	1185.2	
JF-674-1	FNL-56	2133	1463.8	490	488	480	1134	1134.3	1430.6	
RF-205 Ch.		1971	1424.0	1424	840	1880	592.59	662	976.0	
RF-101 Ch.		3504	1319.0	615	666	1050	1314	1268	1527.8	
CD (p=0.05)		248		312	254		233	168.8		
CV (%)		7.42		6.46	5.82		7.82	8.96		

Table 2a (contd.): Seed yield (kg ha⁻¹) of fennel varieties in coordinated trial at different location across the country during 2012-13 to 2014-15

Entries	Code	Pantnagar			Navasari		
		2012-13	2013-14	2014-15	2012-13	2013-14	2014-15
AJ-FNL-2	FNL-47	1898	1736.11	1745.16	1300	2627.3	2569.4
AF 05-1-3	FNL-48	1854	2199.08	2245.18	1633	1789.4	1747.7
UF-157	FNL-49	2037	2268.52	2310.23	1368	2625.0	2490.7
UF-278	FNL-50	2327	2500	2356.86	1368	1777.8	1777.8
HF-119	FNL-51	3044	2754.63	2513.26	1400	1773.2	1777.8
HF-147	FNL-52	2104	2430.56	2481.3	1433	1768.5	1777.8
NDF-45	FNL-53	1826	2407.41	2318.98	1203	1782.4	1740.7
NDF-46	FNL-54	1944	2129.63	2111.02	1340	1555.6	1546.3
JF-671-1	FNL-55	2176	2615.74	2662	1283	1601.9	1601.9
JF-674-1	FNL-56	2493	2476.85	2477.23	1613	1615.7	1652.8
RF-205 Ch.		2733	2430.56	2541.19	1617	2425.9	2148.1
RF-101 Ch.		2037	2592.59	2254.72	1450	2013.9	2004.6
CD (p=0.05)		315	240.9		195	241.9	
CV (%)		6.48	5.93		5.48	7.34	

Table 4b.Performance of proposed genotypes as per *Ramularia* blight disease reaction in CVTS at NRCSS Ajmer

S.No.	Name of entries	2012 -13	2014 -15	Average
1	AJ-FNL -2 (AF -2)(Proposed entry)	18	20	23.5
2	RF -205	44	38	41
3	RF -101	46.7	36	41.35

Table 5. Mean of Ancillary data for the proposed variety tested in CVT during 2012-13 to 2014-15

Entries	AF-2 (AJ-FNL-2)	RF-205 (C)	RF-101 (C)
Character			
50% flowering	98.6	95.6	94.6
Plant height (cm)	156.2	147.8	142.4
No. of branches per plant	8.6	8.9	8.3
Umbel per plant	35	38.2	36.1
Umbellate per umbel	27.8	25.5	24.6
Seeds per umbellate	25	23.8	21.9
Seeds per umbel	429.2	411.4	439.5
Test weight (g)	6.2	6.2	6.2
Days to maturity	175	173	175

Table 6. Essential oil (%) content in seed of the proposed variety tested at NRCSS, at CVT Ajmer during 2014-15

S.No.	Name of entries	Essential oil %	% higher than RF-205	% higher than RF-101
1	AJ-FNL-2 (AF-2)(Proposed entry)	1.9	18.5	11.7
2	RF-205	1.6		
3	RF-101	1.7		

Table 6a. Profiling of essential oil of the proposed variety tested at NRCSS, Ajmer in CVT during 2014-15

Compound in essential oil	AF-2 (AJ-FNL-2)	RF-205 (C)	RF-101 (C)
Alpha Pinene	0.223	0.05	0.034
Camphene	0.029	0.01	0.012
Beta Pinene	0.022	0.008	0.009
Myrecene	0.111	0.046	0.05
Cymene/ Cymol	0.022	0.014	0.012
Gama Terpinene	2.056	1.369	0.541
4-allyl Anisole	40.051	49.51	22.01
Geraniol	0.016	1.804	0.081
Anethol+Estyragol	57.456	46.941	77.176
Geranyl Acetate	0.011	0.247	0.074

Table 6b. Essential oil yield (l ha⁻¹) of proposed fennel variety in CVT at Jobner centre (*Rabi* 2012-13 to 2014-15)

S.No	Name of entries	AF-2 (AJ-FNL-2)	NC-1 RF-205	NC-2 RF-101	% higher than RF-205	% higher than RF-101
1.	2012-13 CVT,Jobner	68.66	59.34	67.29		
2.	2013-14 CVT,Jobner	42.66	27.96	35		
3.	2014-15 CVT, Jobner	26.2	25.24	26.61		
4.	Mean	45.84	37.51	43.08	22.2	6.4

Table 7. Characteristics of AF-2 for identification

S.No	Characteristics	States	Note	Example varieties	Stage of observation (Days after sowing)
1	2	3	4	5	6
1.	Plant height	Medium	3	AF-2	40
		Tall	5		
2.	Foliage intensity of green colour	Very light	1		20
		Light	3	AF-2	
		Medium	5		
		Dark	9		
3.	Fully bloom leaf foliage density	Less	3		10
		Medium	5		
		Dense	7	AF-2	
4.	King umbel base leaf	Droopy	3		30
		Straight	5	AF-2	
5.	Foliage attitude	Erect	3		40
		Semi-erect	5	AF-2	
		Spreading	7		
6.	Foliage density	Sparse	3		40
		Medium	5		
		Dense	7	AF-2	
7.	Leaf density of feathering	Loose	1		30
		Medium	3	AF-2	
		Dense	5		
8.	Fully bloom king umbel leaf	With petiole	1	AF-2	40
		Without petiole	9		
9.	Stem girth	Thick<4.5	1	AF-2	40
		Thin >4.5	9		
10.	1 st internode length	Short	1	AF-2	30
		Long	9		

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