REDESCRIPTION OF *DIAERETIELLA RAPAE* (M'INTOSH) (HYMENOPTERA: BRACONIDAE: APHIDIINAE) WITH MORPHOLOGICAL VARIABILITY OF SEVERAL POPULATIONS FROM INDIA

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ABSTRACT: *Diaeretiella rapae* (M'Intosh) is redescribed with additional of recording morphometric ratios, in addition to original measurement of different body parts. Four populations of *D. rapae* were investigated on the basis of ten character ratios, using numerical methods. The analysis of populations indicated that the specimens reared from different localities showed clear distinction from other populations.

KEY WORDS: Aphidiinae, *Diaeretiella rapae*, morphological variability, systematics.

Aphid parasitoids belonging to the braconid subfamily Aphidiinae (Hymenoptera) are solitary endoparasitoids of aphids (Stary, 1970; 1988). *Diaeretiella rapae* (M'Intosh), a polyphagous and cosmopolitan parasitoids of aphids and very important control agents for aphid pest in a variety of agricultural and horticultural crops (Hagvar and Hofsvang, 1991), most important factor for natural control of mustard aphid (Dhiman, 2007; Dogra et al., 2003; Pike et al., 1999). It was exported from China to the USA for biological control of *Diuraphis noxia* (Mordwilko), a pest of small grains (Bernal and Gonzalez, 1997). Furthermore, *D. rapae* parasitizing several aphid taxa *viz., Aphis ruborum longisetosus, Aphis craccivora, Aphis gossypii, Brachycaudus helichrysi, Brevicoryne brassicae, Hayhurstia atriplicis, Lipaphis erysimi, Macrosiphoniella pseudoartemisae, Macrosiphum (Metopolophium) drihodun, Macrosiphum (Sitobion) rosaeformis, Myzus persicae, Sitobion avenae eleusinae* are recorded from India (Dey & Akhtar, 2007). Knowledge of their taxonomy and diversity has great importance for successful biological control programs.

The aim of the present paper is redescription of *D. rapae* with addition morphmetric ratio which was not present in earlier description along with original measurement of different body parts and taxonomic study using numerical methods of several population of *D. rapae* from selected pest aphids. In our study we have used taxonomic characters with a high content of diagnostic information.

MATERIAL AND METHODS

The specimens for the present study were collected from various parts of India and deposited in National Pusa Collection (NPC), New Delhi. The essential diagnostic characters of the specimens were examined without any special preparation under Leica MZ12 stereo zoom microscope with suitable illumination. Photos were taken with a Leica MZ16 stereomicroscope with integrated Leica photo camera. The captured images were assembled with CombineZP programme

and edited in Adobe Photoshop Elements 2.0. The nomenclatural treatment, morphological terminology and taxonomic characters adopted from Sharkey and Wharton, 1997.

Ten specimens in good condition were selected from four populations of *Diaeretiella rapae* (M'Intosh) (*viz.,* LMNNT= *Lipaphis erysimi* on mustard from Nainital, LMDER= *Lipaphis erysimi* on mustard from Dehra Dun, LMDEL= *Lipaphis erysimi* on mustard from Delhi and MCDEL= *Myzus persicae* on cabbage from Delhi). All specimens were individually numbered and kept aside for recording their measurements.

Eighteen taxonomic characters with a high content of diagnostic information relevant to the parasitoid, *D. rapae* were selected and measurements were taken. All measurements were expressed as ratios as recommended by Tomnic et al. (2005) which were then used for matrix analysis. All the characters and ratios used have been listed in Table 1. The morphometric data was recorded for four populations of *D. rapae* from three different localities (*viz.,* New Delhi, Nainital and Dehradun); on two different hosts (*viz., L. erysimi* and *M. persicae*); on two different host plants (*viz.,* mustard and cabbage). The data was then subjected to cluster analysis using SPSS 10.0.5 software from which a dendrogram was constructed.

RESULTS AND DISCUSSION

Genus *Diaeretiella* Stary, 1960: 242-243.

Type species: *Aphidius rapae* M'Intosh, 1855

Diagnosis: Head transverse to subquadrate, wider than mesosoma at tegulae; occiput margined, antenna filiform with 14 segment in female and 18 in male; eyes medium oval; mandibles bidentate. Notauli developed on ascending part of mesoscutum; stigma large triangular; metacarp (R1) longer than stigmal width; radial sector long; marginal cell incomplete; cubital vein effaced beyond basal cell towards the apex of fore wing; hindwing without any complete cell; costal and subcostal vein developed; propodeum areolated with narrow small central areola. Metasoma of female lanceolate and rounded at apex in male; ovipositor sheaths curved upwards, sparsely hairy.

Diaeretiella rapae (M'Intosh, 1855) (Fig. 1-8)

?*Aphidius vulgaris* Bouche, 1834: 161-162.
Aphidius rapae M'Intosh, 1855: 194.
Aphidius (Trionyx) rapae Curtis, 1860: 73-74.
Diaeretus chenopodii Foerster, 1867:125.
Trioxys piceus Cresson, 1880:260.
Lipolexis chenopodiaphidis Ashmead, 1889: 671.
Aphidius brassicae Marshall, 1896: 597-598.
Diaeretus californicus Baker, 1909: 25.
Diaeretus nipponensis Viereck, 1911: 182.
Diaeretus obsoletus Kurdjumov, 1913: 25-26.
Diaeretus napus Quilis, 1931: 71-72.
Diaeretus croaticus Quilis, 1934: 8-9.
Diaeretus plesiorapae Blanchard, 1940: 45-48.
Diaeretus aphidum Mukerji and Chatterjee, 1950: 4-6.

Female (Fig. 7):

Colour: Head frons and occiput brown; antenna brown; scape, pedicel and base of flagellar segment I yellow. Mesosoma yellow; lobes with slightly brown spot; wing venation brown; legs yellow; femur, tibia and tarsi darkened. Tergum I yellow; remaining metasoma brownish.

Head (Fig. 3,4) transverse to subquadrate, smooth, shiny, sparsely hairy wider than mesosoma at tegulae, 0.92x wider than width of mesoscutum; occiput margined. Eyes (Fig. 3, 4) medium sized, nearly hemispherical with sparse hairs, prominent, strongly convergent towards clypeus; transverse diameter of eye as wide as width of temple; width of gena as wide as 0.24x longitudinal eye diameter; inter-tentorial line 0.37x of facial line, 2.2x as long as tentori-occular line; clypeus transverse, oval, convex, margined frontally, smooth shiny with six to eight long hairs, separated from face by shallow grooves; mandibles broad basally, uniformly narrowed towards apex. Ocelli medium sized, forming an equilateral triangle. Antenna filiform (Fig. 3, 4), 14 segmented, thickened towards apex, about as long as head, mesosoma and half of metasoma combined; antennal socket ocular line 0.43x of socket diameter; scape and pedicel sub-equal to their maximum width; flagellar segment I and II almost 2.26x as long as its maximum width; flagellar segment II 1.30x as long as length of penultimate segment; length of apical segment sub-equal flagellar segment II.

Mesosoma smooth, shiny, sparsely hairy; mesoscutum falling almost vertically to pronotum, without covering it when viewed from side; length of mesosoma 1.37x its height and 1.54x its width, notauli distinct anteriorly, narrow, crenulate but effaced on disc, fore margin slightly prominent. Forewing (Fig. 1) hyaline, length 2.91x its maximum width; stigma triangular, 4.75x longer than wide; length of metacarp (R1) 0.34x length of stigma; 'r' arising from about basal 0.50 stigma, about 0.25 as long as stigmal width; marginal cell incomplete; r-m and mcu absent; submarginal cells confluent. Hindwing (Fig. 2) more than 4.80x as long as wide, SC+R prominent. Legs with hind femur 5.50x as long as wide; length of hind tibia 1.50x length of hind femur; length of hind tarsal segment I 0.60x length of remaining segments combined; length of hind tarsal segment II to V gradually small.

Propodeum (Fig. 5) with small narrow central areola; disc of areola smooth, shiny; transverse carinae arising from either side of mid lateral part of areola reaching spiracles; median carina originating on top of areola run up to postscutellum; few small carinae present around basal region of areola; propodeal spiracle located on lateral propodeal margin.

Metasoma lanceolate, longer than head mesosoma combined; tergum I slender (Fig. 6), costulate, slightly granulate, dilated towards apex, more than 3.43x longer than wide at spiracles, prominent lateral longitudinal carina, more or less coarsely rugose anteriorly, posterior 0.25 smooth; spiracular tubercles poorly visible, sparsely hairy; combined median length of tergum II and III 2.00x of basal with of tergum II, following tergum smooth shiny, sparsely hairy.

Genitalia: Ovipositor sheath straight or slightly curved upwards, about 2.22x longer than its maximum width, bearing 4 to 6 setae; ovipositor curved upwards, ending in a pointed tip.

Measurements (mm±SD): Body length 1.94±0.07; tenterio-ocular line 0.05±0.01, intertentorial line 0.11±0.01, inter-ocellar line 0.12±0.01, facial line 0.30±0.03, tenterio-facial line 0.22±0.01, width of gena 0.05±0.01, longitudinal eye diameter 0.21±0.03, transverse eye diameter 0.11±0.02, width of temple

0.13±0.02, length of F I 0.13±0.01, width of F I 0.05±0.01, length of F II 0.13±0.01, width of F II 0.05±0.01, length of penultimate segment of antenna 0.10±0.01, length of apical segment of antenna 0.21±0.01, length of stigma 0.38±0.03, width of stigma 0.08±0.01, length of metacarp (R1) 0.13±0.02, length of radial vein 0.06±0.01, length of tergum I 0.24±0.02, width of tergum I 0.07±0.01, length of ovipositor sheath 0.12±0.01, width of ovipositor sheath 0.05±0.01.

Male (Fig. 8): Antenna 16 segmented, colour darker than female; mouthparts and tergum I yellowish; leg brownish black; other colourations as female.

Mummy: Dark shining brown.

Material examined: 120♀♀ and 30 ♂♂; INDIA: 60 ♀♀and 10 ♂♂: Delhi, IARI, 14. II. 2007, 06. III. 2007, 21. II. 2008, parasitic on *Lipaphis erysimi* on Mustard, Coll. Mir Samim Akhtar; 20 ♀♀ and 5 ♂♂: Himachal Pradesh, Palampur, 28. III. 2007, parasitic on *Lipaphis erysimi* on Mustard, Coll. Ajay Kumar; Uttarakhand, 25 ♀♀and 10 ♂♂: Nainital, 17. I. 2007, parasitic on *Lipaphis erysimi* on Mustard Coll. Poonam Dev; 15 ♀♀and 5 ♂♂: Uttarakhand, Dehradun, 28. II. 2007, parasitic on *Lipaphis erysimi* on Mustard, Coll. Mir Samim Akhtar.

Distributions: Assam, Himachal Pradesh, Delhi, Jammu and Kashmir, Karnataka, Manipur, Meghalaya, Punjab, Sikkim, Uttar Pradesh.

Morphological variability:

The extent of variation among the various character ratios as indicated by correlation matrix (Table 3) revealed all interactions between various character ratios to be significantly different from each other except that between TL/TW and MS/LED (r=-0.54). However among all the significantly different ratios maximum interaction was shown between the ratios F1T/F2T and F2L/F2W (r=0.45) followed by F2L/F2W and F1L/F1W (r=0.44); F1L/F2L and F2L/F2W (r=-0.41); M1T/M2T and TL/TW (r=-0.41). Significantly lower interaction was shown by all the others, least being shown in four pairs of ratios, i.e. F1L/F2L and MS/LED(r=0.02); F1L/F2L and TO/IT (r=-0.02); M1T/M2T and F2L/F2W (r=0.02); M1T/M2T and F1L/F1W (r=-0.02).

The ratio of length of malar space: longitudinal eye diameter i.e. MS/LED showed minimum deviation followed by the TO/IT ratio (tentorio-ocular line: inter tentorio line) among all the individuals of all the four populations of *D. rapae* studied. Although the ratio of F1L/F2L showed less deviation among the individuals of two populations *viz.,* LMDER and LMDEL but showed more deviation among the members of the other two populations *viz.,* LMNNT and MCDEL. Similarly ratio of F1T/F2T showed less deviation in the two populations *viz.,* LMNNT and LMDEL and more deviation among the members of the other two populations *viz.,* LMDER and MCDEL. The remaining character ratios did not show any particular trend as indicated by the differential values of standard deviations. Therefore from the data it can be concluded that among all the character ratios studied only two i.e. MS/LED and TO/IT can be considered as stable characters (Table 2).

All the four populations were significantly different from each other (F= 7.179; p= 0.0001) (Table 4). However, the cluster of the four populations (Fig. 9), showed that two of them *viz.,* LMDEL and MCDEL to be very closely clustered

(Square Euclidian Distance (SED)= 0.620; both the populations had been collected from the same locality but host plants are different.

Again both the above two populations were closer to LMDER compared to the fourth population LMNNT both from different localities. Among the two populations LMDEL and MCDEL, MCDEL was closer to LMDER (SED= 0.713; localities are different). Comparisons among populations reveal significant differences, *viz.,* LMNNT and LMDER (SED= 1.271), LMDER and LMDEL (SED= 1.534) wherein the localities of collection were different; while among LMNNT and LMDEL (SED= 1.628) and LMNNT and MCDEL (SED= 1.683) both host plants and localities of collection were different.

Analysis of various morphometric ratios by two way multiple factor ANOVA indicated significant variability among *D. rapae* populations from different places, hosts and host plants (Table 5). A clear cut difference among the reared populations of *D. rapae* from Delhi, Nainital and Dehradun could be observed. *D. rapae* females parasitizing *Lipaphis erysimi* on mustard from Nainital (Uttarakhand in northern hill zone) showed distinct variations among some of the characters studied, *viz.,* in general size was larger, with almost concave temples, a semi-oval head, well developed notauli at least anteriorly, propodeal areola with numerous irregular carinae etc. Cluster analysis also revealed that all the four populations were significantly different from each other (F= 7.179; p= 0.0001) (Table 5). However, the cluster of the four populations (Fig. 12), showed that populations collected from Delhi and Dehradun were closer to each other than to the population from Nainital. Further two of the populations from the same locality Delhi but from two different hosts, *L. erysimi* and *M. persicae* and also different host plants, mustard and cabbage were very closely clustered [Square Euclidian Distance (SED) = 0.620]. Again both the above two populations were closer to the population collected from Dehradun but on the host *L. erysimi* on mustard compared to the Nainital population which was on the same host and host plant. Therefore it can be inferred that the place of occurrence might have an influence on the morphological characters as Nainital is situated on a higher altitude compared to both Delhi and Dehradun.

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Figures 1–9. *Diaeretiella rapae*. 1. Forewing, 2. Hindwing, 3. Head lateral, 4. Head frontal, 5. Propodeum, 6. Tergum I, 7. Adult female, 8. Adult male, 9. Dendogram of generalized distances between four populations of *Diaeretiella rapae*.

Table 1. List of characters used in matrix analysis of *D. rapae* populations

Sl. No.	Character Code	Description
	TO	Tentorio-ocular line
	IT	Inter tentorio line
	MS	Length of malar space
	LED	Longitudinal eye diameter
	F1L	Length of flagellar segment I
	F1W	Width of flagellar segment I
	F2L	Length of flagellar segment II
	F2W	width of flagellar segment II
	TL	Length of tergum I
.	TW	Width of tergum I
.	PTL	Length of stigma
.	PTW	Width of stigma
.	F1T	Length of tarsomere I of fore leg
.	F2T	Length of tarsomere II of fore leg
.	M1T	Length of tarsomere I of mid leg
.	M2T	Length of tarsomere II of mid leg
.	H1T	Length of tarsomere I of hind leg
.	H2T	Length of tarsomere II of hind leg
.	TO/IT	Tentorio-ocular line : inter tentorio line
.	MS/LED	Length of malar space : longitudinal eye diameter
.	F1L/F1W	Length of flagellar segment I : width of flagellar segment I
.	F2L/F2W	Length of flagellar segment II : width of flagellar segment II
.	F1L/F2L	Length of flagellar segment I : Length of flagellar segment II
.	TL/TW	Length of tergum I : width of tergum I
.	PTL/PTW	Length of stigma : width of stigma
.	F1T/F2T	Length of tarsomere I : length of tarsomere II of fore leg
.	M1T/M2T	Length of tarsomere I : length of tarsomere II of mid leg
.	H1T/H2T	Length of tarsomere I : length of tarsomere II of hind leg

Table 2. Quantitative character ratios' of various *D. rapae* populations

	TO/IT	MS/LED	F1L/F1W	F2L/F2W	F1L/F2L	TL/TW	PTL/PTW	F1T/F2T	M1T/M2T	H1T/H2T
LMNNT	0.42	0.32	2.33	1.71	1.17	3.25	4.50	1.80	2.00	2.67
	0.40	0.21	2.80	1.50	1.17	2.80	3.50	2.00	2.00	3.00
	0.55	0.28	2.50	2.00	1.25	3.60	3.78	2.00	1.67	2.33
	0.44	0.28	2.00	2.20	1.09	2.25	5.57	2.00	1.80	2.11
	0.42	0.21	2.43	2.00	1.00	4.20	5.40	1.83	1.67	2.14
	0.45	0.21	2.33	2.33	1.00	2.50	4.67	2.00	2.00	2.67
	0.50	0.20	2.67	2.33	1.14	2.67	4.00	1.75	3.00	2.50
	0.40	0.24	2.33	2.40	1.27	2.40	3.67	2.00	1.75	2.00
	0.60	0.23	2.50	1.80	1.67	2.50	5.00	2.00	1.80	2.14
	0.50	0.19	2.00	2.13	1.06	4.50	4.38	2.20	2.20	2.50
Mean	0.47	0.24	2.39	2.04	1.18	3.07	4.45	1.96	1.99	2.41
±SD	0.07	0.04	0.25	0.30	0.19	0.79	0.72	0.13	0.39	0.32
LMDER	0.60	0.23	2.40	2.60	0.92	2.42	4.70	2.57	1.38	2.55
	0.60	0.22	3.00	3.00	0.80	3.00	4.17	2.57	1.50	2.42
	0.56	0.19	3.00	2.60	0.92	2.67	4.11	2.43	1.33	3.00
	0.45	0.22	1.88	2.29	0.94	2.08	3.82	1.71	1.29	2.45
	0.60	0.31	2.75	2.40	0.92	2.67	4.14	1.71	1.20	2.33
	0.70	0.23	1.71	2.40	1.00	2.33	4.17	1.71	1.33	3.00
	0.60	0.23	2.60	2.17	1.00	2.56	3.69	1.50	1.67	2.78
	0.60	0.20	3.50	3.00	0.93	2.75	3.75	2.50	2.00	3.13
	0.60	0.21	2.75	2.60	0.85	3.00	3.40	2.00	1.67	2.50
	0.60	0.20	3.00	3.00	0.80	2.75	3.20	2.57	2.29	3.11
Mean	0.59	0.22	2.66	2.61	0.91	2.62	3.91	2.13	1.56	2.73
±SD	0.06	0.04	0.54	0.31	0.07	0.29	0.43	0.44	0.35	0.31
LMDEL	0.57	0.39	2.40	2.50	0.86	2.10	4.29	1.50	2.17	2.09
	0.45	0.38	2.50	2.60	0.77	2.00	4.33	1.67	2.50	2.00
	0.33	0.33	2.17	2.13	0.76	1.92	3.83	2.17	1.83	2.80
	0.47	0.41	2.17	2.29	0.76	1.85	3.83	1.67	2.00	2.14
	0.40	0.33	2.33	2.29	0.88	1.94	4.50	1.50	2.20	2.14
	0.50	0.32	1.75	1.78	0.88	2.19	3.57	1.89	2.14	2.33
	0.40	0.35	2.00	1.86	0.92	2.19	4.33	2.14	1.88	2.13
	0.40	0.33	2.00	2.29	0.75	2.19	4.50	1.67	2.50	2.21
	0.53	0.37	2.33	2.14	0.93	1.80	3.23	1.83	2.25	2.67
	0.44	0.35	2.00	2.17	0.92	1.88	3.42	2.14	2.50	2.21
Mean	0.45	0.36	2.17	2.20	0.84	2.01	3.98	1.82	2.20	2.27
±SD	0.07	0.03	0.23	0.25	0.07	0.15	0.47	0.26	0.25	0.26
MCDEL	0.50	0.38	2.50	2.80	1.07	2.27	3.67	2.80	2.75	2.44
	0.45	0.40	2.50	2.80	1.07	2.27	3.85	2.67	2.00	2.50
	0.50	0.40	2.17	2.20	1.09	2.45	3.71	2.80	1.71	2.31
	0.50	0.50	1.67	1.83	1.13	2.33	3.82	2.11	1.88	2.92
	0.44	0.48	2.14	2.29	1.25	2.40	3.67	2.00	1.86	2.50
	0.40	0.40	2.29	1.78	1.14	2.33	3.57	1.88	1.67	2.57
	0.33	0.40	3.00	2.00	0.92	2.50	3.00	2.00	1.67	2.57
	0.44	0.40	3.00	2.33	0.85	1.35	3.57	2.00	1.88	2.40
	0.47	0.43	2.75	2.17	1.13	1.86	3.71	1.64	2.20	2.50
	0.36	0.39	2.33	2.60	1.08	1.92	3.71	2.67	1.50	2.38
Mean	0.44	0.42	2.43	2.28	1.07	2.17	3.63	2.26	1.91	2.51
±SD	0.06	0.04	0.41	0.36	0.11	0.36	0.24	0.43	0.35	0.17

LMNNT= *Lipaphis erysimi* on mustard from Nainital, LMDER= *Lipaphis erysimi* on mustard from Dehra Dun, LMDEL= *Lipaphis erysimi* on mustard from Delhi and MCDEL= *Myzus persicae* on cabbage from Delhi, TO= Tentorio-ocular line, IT= Inter tentorio line, MS=Length of malar space, LED= Longitudinal eye diameter, F1L= Length of flagellar segment I, F1W= Width of flagellar segment I, F2L= Length of flagellar segment II, F2W= Width of flagellar segment II, TL= Length of tergum I, TW= Width of tergum I, PTL= Length of stigma, PTW= Width of stigma, F1T= Length of tarsomere I of fore leg, F2T= Length of tarsomere II of fore leg, M1T= Length of tarsomere I of mid leg, M2T= Length of tarsomere II of mid leg, H1T= Length of tarsomere I of hind leg, H2T= Length of tarsomere II of hind leg.

Table 3. Correlation coefficient of different character ratios' of various populations of *D. rapae*

	TO/IT	MS/LED	F1L/F1W	F2L/F2W	F1L/F2L	TL/TW	PTL/PTW	F1T/F2T	M1T/M2T	H1T/H2T
TO/IT	1.00									
MS/LED	-0.41	1.00								
F1L/F1W	0.21	-0.28	1.00							
F2L/F2W	0.40	-0.18	0.44	1.00						
F1L/F2L	0.02	-0.02	-0.09	-0.41	1.00					
TL/TW	0.22	-0.54	0.13	-0.09	0.24	1.00				
PTL/PTW	0.04	-0.29	-0.23	-0.09	0.16	0.29	1.00			
F1T/F2T	0.07	-0.04	0.23	0.45	0.06	0.11	-0.16	1.00		
M1T/M2T	-0.21	0.18	-0.02	0.02	-0.07	-0.14	-0.10	-0.09	1.00	
H1T/H2T	0.30	-0.26	0.30	0.11	-0.05	0.13	-0.38	0.26	-0.15	1.00

TO= Tentorio-ocular line, IT= Inter tentorio line, MS=Length of malar space, LED= Longitudinal eye diameter, F1L= Length of flagellar segment I, F1W= Width of flagellar segment I, F2L= Length of flagellar segment II, F2W= Width of flagellar segment II, TL= Length of tergum I, TW= Width of tergum I, PTL= Length of stigma, PTW= Width of stigma, F1T= Length of tarsomere I of fore leg, F2T= Length of tarsomere
II of fore leg, M1T= Length of tarsomere I of mid leg, M2T= Length of tarsomere II of mid leg, H1T= Length of tarsomere I of hind leg, H2T= Length of tarsomere II of hind leg

Table 4. Two way multiple factor ANOVA of various populations of *D. rapae*

Source of Variation	SS	df	MS	F	P	F crit.
Populations	2.21	3	0.74	7.18	0.0001	3.84
Character ratio	431.48	9	47.94	466.67	0.0000	2.46
Interaction	16.44	27	0.61	5.93	0.0000	1.79
Within	36.98	360	0.10			
Total	487.12	399				

SS=Sum of square; df= Degree of freedom; MS= Mean sum of square; F= Calculated value of F; P= Probability; F crit. =Table value of F at 1%