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Hypopygia of species in the *cioni* species group, and *crassiscapus* species group of *Entedon* Dalman (Hymenoptera: Eulophidae) in Turkey and some European species

Mikdat Doğanlar [1*] and Oğuzhan Doğanlar[2]

1- Mustafa Kemal University, Faculty of Agriculture, Department of Plant Protection,TR-31034, Hatay, Turkey, Corresponding author
2- Ağrı İbrahim Çeçen University, Science and Art Faculty, Department of Biology, 04200, Ağrı, Turkey

Corresponding author Email : doganlar@mku.edu.tr

ABSTRACT: The species of *Entedon* Dalman with complete frontal fork were studied. One species of the *crassiscapus* species group, *E. crassiscapus* Erdös, and 5 species of the *cioni* species group, *E. cionobius* Thomson, *E. cioni* Thomson, *E. leucocnemus* Erdös in Turkey and *E. methion* Walker, *E. tibialis* (Nees) in Germany, of genus *Entedon* Dalman (Hymenoptera: Eulophidae: Entedoninae) were collected. Hypopygia of the species were studied. By aids of the new characters the identification key to species were provided.

***Keywords*:** Hymenoptera (Eulophidae), *Entedon* species with complete frontal fork, Turkey, Germany.

INTRODUCTION

The morphology of hypopygia in the taxonomy of Pteromalidae (Hymenoptera: Chalcidoidea) has been studied for separating the species of *Mesopolobus* Westwood, 1833 by Graham (1969), for the species of *Pachyneuron* Walker, 1833 and *Euneura* Walker, 1844 by Doğanlar (1986) and for the species of *Dibrachys* Förster, 1856 by Doğanlar (1987). In the taxonomy of Eulophidae (Hymenoptera: Chalcidoidea) Graham (1987, 1991) used the morphology of hypopygia in the classification of species of some genera in Tetrastichinae, Doğanlar (1991a, 1991b) for some species of Ormyridae, and Tarla et al. (2010) for species of genus *Oopristus* Steffan, 1968 in Monodontomerinae (Torymidae).

The complete frontal fork was applied to define the *cioni* species group of genus *Entedon* as main character by Graham (1963, 1971, including *E. crassiscapus* Erdös, 1944), and Thomson (1878) distinguished and described *E. cioni* by the arms of frontal fork reaching to the eyes and by the male antennal clava with single segment. Graham (1963) gave the characters of the group as follows: complete impressed frontal fork, mouth opening at most about twice as broad as the length of malar space, anterior margin of clypeus not produced. Askew (1991) added two antennal characters: female with F1 at least 1.3 times as long as pedicel, male with four separate funicle segments and one-segmented clava. Askew (1991) listed 15 species in the *cioni* group, and provided an identification key for them, and stated that this extended definition removes *E. crassiscapus* and the related one, *E. albifemur*Kamijo, 1988, from the cioni group, and also excludes *E. albiscapus* Askew, 1991.

Gumovsky (1997) created the *crassiscapus* group of *Entedon* including *E. crassiscapus*, *E. albifemur*, and listed 18 species, including *E. albiscapus,* in the *cioni* group. Gumovsky (1995) revised the species of *Entedon* associated with *Cionis* weevils (Col. Curculionidae) in Ukraine, and listed three species, *E. cioni* Thomson, 1878, *E. cionobius* Thomson, 1878, and *E. fructicola* Gumovsky, 1995, and provided an identification key for them. Doğanlar (1985) recorded *E. cionobius* in Erzurum, Turkey.

In this work the species in the *cioni* species group, and *crassiscapus* group, with complete frontal fork, of *Entedon* from Turkey, and some European species were studied. By aids of some morphological characters, mainly on their hypopygia, an identification key was created for the species with complete frontal fork of the genus *Entedon* in Turkey.

MATERIALS AND METHODS

This study is based upon examination and identification of the specimens collected from several parts of Turkey. The examined specimens were deposited in Insect Museum of Plant Protection Department, Agriculture Faculty, Mustafa Kemal University, Antakya, Hatay, Turkey (MKUI). Specimens were collected by sweeping and putting the whole contents of the swept materials directly in 96 % ethanol. After sorting the material, individuals were mounted on cards for further morphological studies. The species were identified by following the keys of Graham (1971), Askew (1991), Gumovsky (1995) and Gumovsky & Boyadzhiev (2003).The hypopygia were separated from metasoma by dissecting and slide mounted in Canada balsam, the other parts of the metasoma were replaced on its own card near its mesosoma. Wings and antennae of some paratypes were slide-mounted in Canada balsam. Photographs of diagnostic characters of the genera were taken by using of Leica DM 5500 B microscope with a digital Leica DFC 295 camera attached to it.

Terminology and abbreviations

Morphological terminology follows Graham (1969) in hypopygia as in Fig. 1, Gibson (1997)and Gumovsky & Boyadzhiev (2003). Abbreviations used in the key and descriptions are: OOL= shorter distance between ocello-ocular line POL= distance between posterior ocelli, F1-4 = funicular segments. The name of some parts of hypopygium given in Fig. 1.

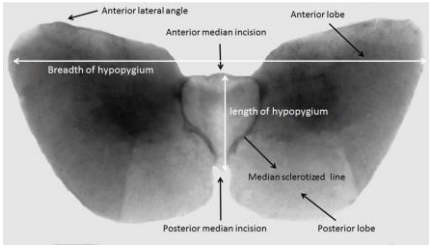

Figure 1. Hypopygium of Entedon cionobius Thomson.

RESULTS AND DISCUSSION

Key to female of the species with complete frontal fork of Entedon

1-Trochanters hyaline, petiole stout, wider than long, eyes densely setose, median area of propodeum reticulated; forewing speculum closed; front tibia with a single dark metallic streak on dorsal surface; femora broadly darkened and metallic medially; hypopygium (Fig.2b, c) with anterior median incision broadly C-shaped, antero-lateral angle straight; anterior lobe narrow, distally circular, posterior lobe almost straight, hypopygium almost 7 times as broad as median length; median sclerotized line reaching only posterior 1/3 of hypopygium, median sclerotized area almost circular; metasoma apically pointed..…….....*E. crassiscapus* Erdös

-Trochanters dark; petiole reduced, strongly transverse, eyes moderately setose; median area of propodeum coriaceous or smooth, front tibiae dark without pale stripe or with two pale longitudinal stripes; the other characters variable……...2

2-Front tibiae dark without pale stripe, hind tibia with only apical one-fifth or less pale(Fig. 6 c, d).; malar space long, more than half the height of eye; antennae long, pedicel plus flagellum at least slightly longer than breadth of head; hypopygium (Fig. 6e, f) with anterior median incision broadly reverse M-shaped, antero-lateral angle circular; anterior lobe broad, apically circular, posterior lobe wide, acutely pointing towards posterior median incision , hypopygium 2.6 times as broad as length; median sclerotized line reaching anterior median incision of hypopygium, median sclerotized area distinctly longer than broad; metasoma 1.2-1.3 times as long as rest of body…....*E. methion* Walker

-Front tibiae with two pale longitudinal stripes; mid and hind tibiae pale at least over apical one-third or more, sometimes entirely pale; the other characters variable.……...……3

3-Middle and hind tibiae with complete dark bands basally which occupy at least half of tibial length (Fig.4 c, d, 5 b, c)…….....….4
-Middle and hind tibiae entirely pale (Fig. 3b, c).....……5
4-Metasoma ovate, 1.3-1.7 times as long as broad and almost as long as mesosoma; antennal flagellum relative short and broad, F1 at most 2.7 times as long as broad; clava not more than twice as long as broad; scutellum only 1.2 times as long as broad; hypopygium (Fig. 4 d, e) with anterior median incision broadly V-shaped, antero-lateral angle angular; anterior lobe broad, apically acute, posterior lobe wide, its margin almost straight, hypopygium 4.3 times as broad as length; median sclerotized line reaching above half of hypopygium, median sclerotized area almost longer than broad; …….....……..*E. cionobius* Thomson
-Metasoma lanceolate, more than 3 times as long as broad and longer than head plus mesosoma; antennal flagellum long and slender, pedicel plus flagellum about 1.1 times breadth of head; F1 3.5-4.5 times as long as broad, distinctly longer than F2, clava and scutellum more elongated (Askew 1991)……..….....…*E. cioni* Thomson
5- Frons with only 2-3 upwardly pointing setae above each arm of frontal fork;pedicel plus flagellum at least slightly shorter than breadth of head; hypopygium (Fig. 3d, e) with anterior median incision C-shaped, antero-lateral angle straight; anterior lobe narrow, apically acute, posterior lobe wide, its margin almost straight, hypopygium 4 times as broad as length; median sclerotized line reaching about half of hypopygium, median sclerotized area almost triangular; metasoma short ovate, 1.1-1.4 times as long as broad, about as long as mesosoma and obtusely angled at apex…….. .....….E. *leucocnemus* Erdös
-Frons with about 10 upwardly pointing setae above each arm of frontal fork; pedicel plus flagellum distinctly longer than breadth of head; hypopygium (Fig. 7e, f) with anterior median incision very small, V-shaped, antero-lateral angle straight; anterior lobe broad, apically angular, posterior lobe wide, acutely pointing towards posterior median incision , hypopygium 2.1 times as broad as length; median sclerotized line reaching to half of hypopygium, median sclerotized area distinctly longer than broad; metasoma long ovate, slightly longer than rest of body, acutely angled at apex, with last tergite 1.5 times as broad basally as median length….....……*E. tibialis* (Nees)

Species group crassiscapus (Gumovsky, 1997, 1998)
Entedon crassiscapus Erdös, 1944
(Figs. 2 a-c)

Entedon(*Trochentedon*) *crassiscapus* Erdös, 1944: 61.
Entedon(*Dolichentedon*) *flavicrus* Erdös, 1944:38.
Entedon(*Entedon*) *crassiscapus* Erdös, Gumovsky, 1997: 33; Gumovsky & Boyadzhiev, 2003:13.

Diagnosis: Antenna (Fig. 2 a) with F1 almost as long as pedicel, 1.7 times as long as broad, slightly longer tan F2; the latter 1.5 times as long as broad; F3 quadrate; clava 2.5 times as long as broad; hypopygium (Fig.2b, c)with anterior median incision broadly C-shaped,antero-lateral angle straight; anterior lobe narrow, distally circular, posterior lobe almost straight, hypopygium almost 7 times as broad as median length; median sclerotized line reaching only posterior 1/3 of hypopygium, median sclerotized area almost circular; posterior median incision as in Fig.2c. The other characters were stated in the identification key.

Material examined: Turkey: Adıyaman, Besni, Kızıliniş, 2♀♀, 17. Iv. 2005, swept from lent field (E. Çıkman).
Host: *Mordellistena* spp. (Col. Mordellidae) in stems of *Artemisia* spp. (Asteraceae) (Boucek &Askew 1968; Gumovsky 1998; Gumovsky & Boyadzhiev 2003).

***Distribution*:** Western and Central Europe, Far East Russia, Japan, Korea (Boucek &Askew 1968; Gumovsky 1998; Gumovsky & Boyadzhiev 2003); Turkey (New record).

Species group of cioni (Askew, 1991; Gumovsky, 1997)
Entedonleucocnemus Erdös, 1944
(Figs. 3 a-e)

Entedonleucocnemus Erdös, 1944:40.
Entedonleucocnemus Erdös, Askew, 1991:222, 224; Gumovsky & Boyadzhiev, 2003:14.

Diagnosis: Antenna (Fig. 3 a) with F1 almost as long as pedicel, 2.5 times as long as broad, distinctly longer tan F2; the latter 1.8 times as long as broad; F3 slightly longer than broad; clava 2.5 times as long as broad;hypopygium (Fig. 3d, e) with anterior median incision C-shaped, antero-lateral angle straight; anterior lobe narrow, apically acute, posterior lobe wide, its margin almost straight, hypopygium 4 times as broad as length; median sclerotized line reaching about half of hypopygium, median sclerotized area almost triangular; posterior median incision as in Fig. 3e. The other characters were stated in the identification key.

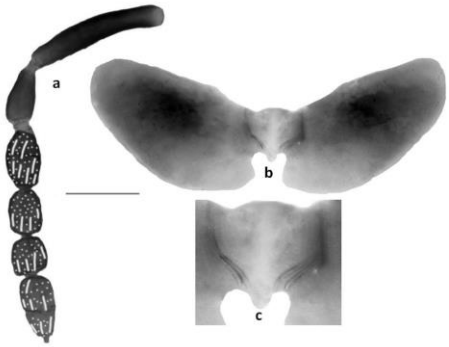

Figure 2. Entedon crassiscapus Erdös. a. antenna; b. hypopygium; c. median area of hypopygium. Scale bar for a= 0.05 mm; for b = 0.01 mm and c=0.005 mm

***Materials examined*:** Turkey:Çankırı, IlgazMnt., Karpınar meadow, 41 00 44 N, 33 38 47 E, 1700 m, 3♀♀, swept from pasture (O. Doğanlar); Kastamonu, Centrum, Bulacık vil. 41 17 26 N, 33 46 50 E, 1080 m, 1♀, 13. vi. 2003, swept from pasture (O. Doğanlar); Devrekani, 41 37 09 N, 33 50 12 E, 1094 m, 1♀, 1♂, 13. vi. 2003, swept from pasture (O. Doğanlar).

Host: unknown
Distribution: Hungary (Erdös, 1944); the former Czechoslovakia (Boucek & Askew, 1968); Turkey (New record).

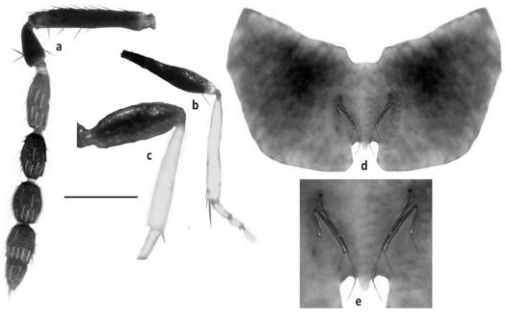

Figure 3. Entedon leucocnemus Erdös. a. antenna; b. mid leg; c. hind leg; d. hypopygium; e. median area of hypopygium. Scale bar for a= 0.05 mm; for b and c= 0.1 mm; for d=0.01mm; for e=0.005 mm

Entedon cionobius Thomson, 1878
(Figs. 1, 4 a-f)
Entedon cionobius Thomson, 1878:247.
Entedon fructicola Gumovsky, 1994(1995):45.
Entedon (*Entedon*) *cionobius* Thomson, Gumovsky, 1997:33; Gumovsky & Boyadzhiev, 2003:14.

Diagnosis: Antenna (Fig. 4 a) with F1 almost twice as long as pedicel, 3.4 times as long as broad, distinctly longer tan F2; the latter 2.6 times as long as broad; F3 1.4 times as long as broad; clava 2.8 times as long as broad, tip of spicula bifid; hypopygium (Fig. 4 d, e) with anterior median incision broadly V-shaped, antero-lateral angle angular; anterior lobe broad, apically acute, posterior lobe wide, its margin almost straight, hypopygium 4.3 times as broad as length; median sclerotized line reaching above half of hypopygium, median sclerotized area almost longer than broad; posterior median incision as in Fig. 4 e. The other characters were stated in the identification key.

Materials examined: Turkey:Hatay, Altınözü, Hanyolu vil. 1♀, 1♂, 22.iv.2003, swept from leaves of *Prunus amygdali* (M. Doğanlar).
Host: *Cionus* spp., *Cleopus pulchellus*, *Stereonychus fraxini* on *Scrophularia nodosa* and *Verbascum* spp. (Askew, 1991; Gumovsky, 1994; 1997a; 1997b).

Distribution: Europe (Boucek & Askew, 1968; Askew, 1992; Gumovsky, 1997b); Bulgaria (Gumovsky & Boyadzhiev, 2003); Turkey (Doğanlar, 1985).

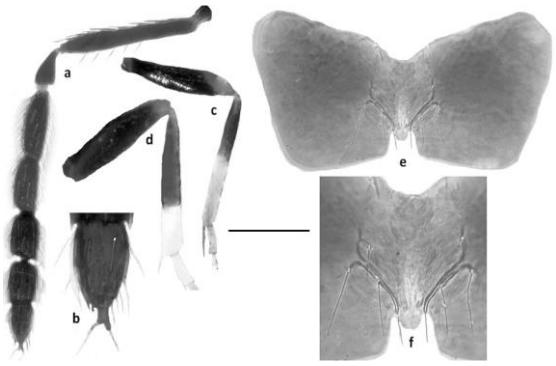

Figure 4. Entedon cionobiusThomson. A. antenna; b. last segment of clava; c. mid leg; d. hind leg; e. hypopygium; f. median area of hypopygium. Scale bar for a= 0.05 mm; for c and d= 0.1 mm; for e=0.01mm; for b and e=0.005 mm

Entedon cioni Thomson, 1878
(Figs. 5 a-c)
Entedon cioni Thomson, 1878:246.
Entedon lanceolatus Erdös, 1944:36.
Entedon cioni Thomson, Boucek & Askew, 1968:79; Graham, 1971:355; Gumovsky,1995: 44.
Entedon lanceolatus Erdös, Boucek & Askew, 1968:79; Gumovsky,1995: 44.

Diagnosis: Diagnostic characters of female were taken from Askew (1991) and given in the identification key. The characters of male is similar to female, except as follows: antenna (Fig. 5 a) with 4 funicular segments and one-segmented clava; pedicel almost as long as broad, F1 2.67 times as long as broad, 1.5 times as long as F2, F2-F4 1.7 times as long as broad, clava almost twice as long as broad.

Materials examined: Turkey: Adıyaman, Besni, Kızıliniş, 1♂, 17. Iv. 2005, swept from lent field (E. Çıkman).
Host: *Cionus* spp. (Boucek & Askew, 1968; Gumovsky, 1994).
Distribution: Europe, Sweden, Britain, Germany, Norway, Hungary (Boucek & Askew, 1968), Ukraine (Gumovsky, 1994), Turkey (New record).

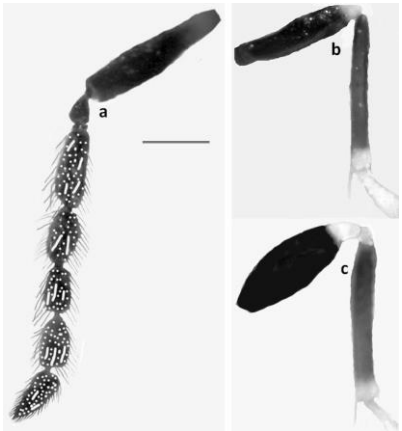

Figure 5. Entedon cioni Thomson.A. antenna; b. mid leg; c. hind leg. Scale bar for a= 0.05 mm; for b and c= 0.1 mm

Entedon methion Walker, 1839
(Figs. 6 a-f)
Entedon methion Walker, 1839:105.
Sympiesis methion (Walker, 1839), De Gaulle 1919: 58 (as Sympiesis nethion); Thomson, 1955:
Entedon (Chlorentedon) györfii Erdös, 1954: 347; Askew, 1991:224.
Entedon györfii Erdös, Boucek &Askew, 1968:83; Askew, 1991:224.

Diagnosis: Antenna (Fig. 6 a) with F1 almost 2.33 times as long as pedicel, 7 times as long as broad, distinctly longer tan F2; the latter 4 times as long as broad; F3 3.4 times as long as broad; clava 5 times as long as broad, without spicula (Fig.6 b); hypopygium (Fig. 6e, f) with anterior median incision broadly reverse M-shaped, antero-lateral angle circular; anterior lobe broad, apically circular, posterior lobe wide, acutely pointing towards posterior median incision , hypopygium 2.6 times as broad as length; median sclerotized line reaching anterior median incision of hypopygium, median sclerotized area distinctly longer than broad; posterior median incision as in Fig. 6f. The other characters were stated in the identification key.

Materials examined: Germany: Göttingen, Göhrenberg, 2♀♀, 18.vii. 1983, reared from bark of *Pinus* sp. (M. Doğanlar).
Host: unknown.
Distribution: Australia, New Zealand (Askew, 1991; Boucek, 1988);Peoples' Republic of China (Zhu & Huang, 2001); Croatia (Boucek, 1977); Czechoslovakia, Germany, Hungary, Yugoslavia, Netherlands, Sweden, United Kingdom (Walker , 1839; Askew, 1991; Boucek & Askew, 1968); Nearctic, United States of America (Schauff , 1988).

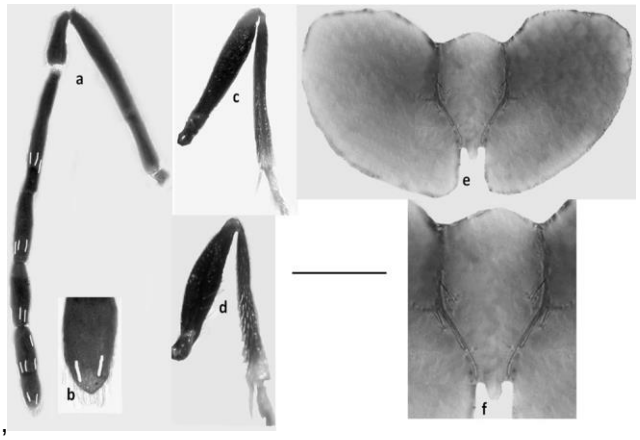

Figure 6. Entedon methion Walker. a. antenna; b. last segment of clava; c. mid leg; d. hind leg; e. hypopygium; f. median area of hypopygium. Scale bar for a= 0.05 mm; for c and d= 0.1 mm; for e=0.01mm; for b and e=0.005 mm

Entedon tibialis (Nees, 1834)
(Figs. 7 a-f)
Eulophus tibialis Nees, 1834:171
Entedon euphorion Walker, 1839:105.
Entedon (*Dolichentedon*) *longicornis* Erdös, 1944:22.
Entedon euphorion Walker, Graham, 1971:356; Askew, 1991:224.
Eulophus tibialis Nees, Boucek, 1994: 117.

***Diagnosis*:** Antenna (Fig. 7 a) with F1 almost 1.75 times as long as pedicel, 3 times as long as broad, distinctly longer tan F2; the latter 2.3 times as long as broad; F3 2.1 times as long as broad; clava 4.2 times as long as broad, with a small spicula (Fig. 7 b);hypopygium (Fig. 7e, f) with anterior median incision very small,V-shaped, antero-lateral angle straight; anterior lobe broad, apically angular, posterior lobe wide, acutely pointing towards posterior median incision , hypopygium 2.1 times as broad as length; median sclerotized line reaching to half of hypopygium, median sclerotized area distinctly longer than broad; posterior median incision as in Fig. 7f. The other characters were stated in the identification key.

***Materials examined*:** Germany: Hesse, Bad Soden Salmünster, 2♀♀, 27.vii.1983 (R. Schopf); Göttingen, Weende, 1♀, 23.vii.1983, reared from bark of *Picea abies* (M. Doğanlar); Göhrenberg, 4♀♀, 20.vii.1983, reared from bark of *Quercus* sp. (M. Doğanlar).
Host: Xylophagous beetles, in particular *Scolytus* sp. on *Quercus* ,*Scolytus intricatus* (Askew, 1991).
Distribution: Europe Czechoslovakia, Germany, United Kingdom, Hungary, Romania, Italy, Netherlands (Erdös, 1944, 1951, 1956; Boucek & Askew, 1968; Szelenyi, 1981; Askew, 1991);Croatia (Boucek, 1977); Bulgaria, Trace (Gumovsky & Boyadzhiev, 2003); New Zealand (Boucek, 1977; Askew 1991).

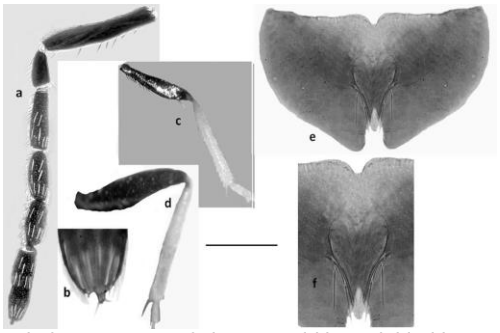

Figure 7.*Entedon tibialis* Szelenyi. a. antenna; b. last segment of clava; c. mid leg; d. hind leg; e. hypopygium; f. median area of hypopygium. Scale bar for a= 0.05 mm; for c and d= 0.1 mm; for e=0.01mm; for b and e=0.005 mm

CONCULSION

The technique discussed in this paper provides an interactive approach in which the decision maker can search for an acceptable solution of the multi-objective optimization problem. The proposed method to solve multiobjective linear programming problem is better than many existing methods as the concept of bound is used in the iteration.

If we substitute some values to a_i , α_i in multi-objective linear programming problem (3.1), it reduces into single objective LPP. This discussion also holds in the case as given by by Kanniappan and Thangavel (1998). The same problem for integer solution was studied by Bhargava and Sharma (2003).

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