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FUZZY SOFT BI-IDEALS OVER TERNARY GAMMA SEMIRINGS

E. MEERA PRASAD, D. MADHUSUDHANA RAO, G. SURESH KUMAR[1], AND M. VASANTHA

ABSTRACT. The concept of fuzzy soft ternary Γ-semiring (FSTGSR) and fuzzy soft bi-ideal over ternary Γ-semiring are introduced and investigate the properties.

1. INTRODUCTION

Many researchers are focused on ternary operations in algebraic structure in recent years. Seetha Mani et. al. [12] obtain the properties for prime radicals in ternary semigroups. prime radicals in ternary semigroups. Srimannarayana et. al. [13,14], studied le-ternary semi groups and Vasantha et. al. [17] on trio ternary gamma semi groups. Fuzzy set theory is used in many disciplines, even in the expert systems [18] for prediction of depth of cut in abrasive water jet machining process. Leelavathi et. al. [1–4] introduced nabla integrals, differentials and also studied nabla dynamic equations on time scales.

In 2017, Ravathi, D. M. Rao [6, 7] introduced the notion of "Fuzzy Ideals in Ternary Gamma semirings". In the year 2018, Muralikrishna Rao [5] studied the same concepts in ordered gamma semirings, T. S. Rao et. al. [15] used Γ (Gamma)- soft sets in application of decision making problem and in [16] obtained some properties on partially ordered soft ternary semi groups. In the 2019, Satish et. al. [8] introduced the concept of fuzzy soft ternary gamma semiring. Further, in the year 2020, [9–11] they investigated about the properties of fuzzy

[1]*corresponding author*

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soft ideals, fuzzy soft quasi ideals in ternary gamma semiring". Throughout this paper we indicate "ternary gamma semiring" as TGSR, "Fuzzy soft ternary gamma Semiring" as FSTGSR, "Fuzzy Soft Quasi ideal" as FSQI, "Fuzzy soft Bi-ideal" as FSBI and "fuzzy sub sets" as FSs unless otherwise stated.

For preliminaries refer the references [8–11].

2. Fuzzy Soft Bi-Ideals(FSBI) over Ternary Gamma Semirings(TGSR)

In this section we introduce the notion of FSBI and characterise FSBI over TGSR.

Definition 2.1. *Let M be a TGSR, E be a "parameter set" and $A \subset E$. Let f be a mapping given by $f : A \to F(M)$ where $F(M)$ denotes the set of all FSs of M. Then (f, A, Γ) is known as a "fuzzy soft bi- ideal(FSBI)" over M if and only if $\forall a \in A$, the corresponding $FSf_a : M \to [0, 1]$ is a "fuzzy bi- ideal" of M, i.e.,*

(i) $f_a(j + m) \geq \min\{f_a(j), f_a(m)\}$,

(ii) $f_a(j\alpha m\beta z\gamma s\delta u) \geq \max\{f_a(j), f_a(z), f_a(u)\}\forall j, m, z, s, u \in M, \alpha, \beta, \gamma, \delta \in \Gamma$.

Definition 2.2. *Let M be a $TGSR$, E be a "parameter set" and $A \subseteq E$. Let f be a mapping given by $f : A \to F(M)$ where $F(M)$ denotes the set of all FSs of M. Then (f, A, Γ) is known as a"fuzzy soft quasi ideal(FSQI) over M if and only if $\forall a \in A$, the corresponding $FSf_a : M \to [0, 1]$ is a"fuzzy quasi ideal of M". i.e. A FSS f_a of TGSR M is called a "fuzzy quasi ideal" i.e.*

(i) $f_a(j + m) \geq \min\{f_a(j), f_a(m)\}$,

(ii) $f_a \circ \chi_M \circ \chi_M \cap \chi_M \circ f_a \circ \chi_M \cap \chi_M \circ \chi_M \circ f_a \subseteq f_a \quad \forall j, m \in M$,

where χ_M is the characteristic function of M.

Theorem 2.1. *Let (f, F, Γ) and (g, G, Γ) be $FSBIs$ over TGSR M. Then $(f, F, \Gamma) \cap (g, G, \Gamma)$ is a $FSBI$ over M.*

Proof. By the Definition 2.2, defined in [6], we have $(f, F, \Gamma) \cap (g, G, \Gamma) = (h, H, \Gamma)$ where $H = F \cup G$,

$$h_p = \begin{cases} f_p, & \text{if } p \in F - G, \\ g_p, & \text{if } p \in G - F \text{ for all } p \in F \cup G, x \in M, \\ f_p \cap g_p, & \text{if } p \in F \cap G. \end{cases}$$

Case-1: $h_p = f_p$ if $p \in F - G$ Then h_p is "Fuzzy Bi-ideal" of M because (f, F, Γ) FSBI over M.

Case-2: $h_p = g_p$ if $p \in G - F$ Then h_p is "Fuzzy Bi-ideal" of M because (g, G, Γ) FSBI over M.
Case-3: If $p \in F \cap G$ and $j, m, z, s, u \in M$, α, β, $\gamma \in \Gamma$, $h_p = f_p \cap g_p$ and

$$\begin{aligned} h_p(j+m) = (f_p \cap g_p)(j+m) &= \wedge[f_p(j+m), g_p(j+m)] \\ &\geq \wedge\{\wedge[f_p(j), f_p(m)], \wedge[g_p(j), g_p(m)]\} \\ &= \wedge\{\wedge[f_p(j), g_p(j)], \wedge[f_p(m), g_p(m)]\} \\ &= \wedge\{[f_p \cap g_p](j), [f_p \cap g_p](m)\} = \wedge[h_p(j), h_p(m)] \end{aligned}$$

Now,

$$\begin{aligned} h_p(j\alpha m\beta z\gamma s\delta u) &= (f_p \cap g_p)(j\alpha m\beta z\gamma s\delta u) \\ &= \wedge\{f_p(j\alpha m\beta z\gamma s\delta u), g_p(j\alpha m\beta z\gamma s\delta u)\} \\ &\geq \wedge\{\vee[f_p(j), f_p(z), f_p(u)], \vee[g_p(j), g_p(z), g_p(u)]\} \\ &= \vee\{\wedge[f_p(j), g_p(j)], \wedge[f_p(z), g_p(z)], \wedge[f_p(u), g_p(u)]\} \\ &= \vee\{(f_p \cap g_p)(j), (f_p \cap g_p)(z), (f_p \cap g_p)(u)\} \\ &= \vee[h_p(j), h_p(z), h_p(u)]. \end{aligned}$$

Hence, h_p is a "fuzzy Bi-Ideal of M". Therefore, $(f, F, \Gamma) \cap (g, G, \Gamma)$ is a FSBI over M. □

Theorem 2.2. *Let* (f, F, Γ) *and* (g, G, Γ) *be FSBIs over TGSR* M*. Then* $(f, F, \Gamma) \cup (g, G, \Gamma)$ *is a FSBI over* M*.*

Proof. By the Definition 3.3, defined in [6], we have $(f, F, \Gamma) \cup (g, G, \Gamma)$, where $H = F \cup G$ and

$$h_p = \begin{cases} f_p, & \text{if } p \in F - G, \\ g_p, & \text{if } p \in G - F \text{ for all } p \in F \cup G, x \in M, \\ f_p \cup g_p, & \text{if } p \in F \cap G. \end{cases}$$

Case-1: $h_p = f_p$ if $p \in F - G$ Then h_p is "Fuzzy Bi-ideal" of M because (f, F, Γ) FSBI over M.
Case-2: $h_p = g_p$ if $p \in G - F$ Then h_p is "Fuzzy Bi-ideal" of M because (g, G, Γ) FSBI over M.

Case-3: If $p \in F \cap G$ and $j, m, z, s, u \in M$, α, β, $\gamma \in \Gamma$, $h_p = f_p \cup g_p$ and

$$\begin{aligned}
h_p(j+m) = (f_p \cup g_p)(j+m) &= \wedge[f_p(j+m), g_p(j+m)] \\
&\geq \vee\{\wedge[f_p(j), f_p(m)], \wedge[g_p(j), g_p(m)]\} \\
&= \wedge\{\vee[f_p(j), g_p(j)], \vee[f_p(m), g_p(m)]\} = \wedge\{[f_p \cup g_p](j), [f_p \cup g_p](m)\} \\
&= \wedge[h_p(j), h_p(m)]
\end{aligned}$$

and

$$\begin{aligned}
h_p(j\alpha m\beta z\gamma s\delta u) &= (f_p \cup g_p)(j\alpha m\beta z\gamma s\delta u) \\
&= \vee\{f_p(j\alpha m\beta z\gamma s\delta u), g_p(j\alpha m\beta z\gamma s\delta u)\} \\
&\geq \vee\{\vee[f_p(j), f_p(z), f_p(u)], \vee[g_p(j), g_p(z), g_p(u)]\} \\
&= \vee\{\vee[f_p(j), g_p(j)], \vee[f_p(z), g_p(z)], \vee[f_p(u), g_p(u)]\} \\
&= \vee\{(f_p \cup g_p)(j), (f_p \cup g_p)(z), (f_p \cup g_p)(u)\} \\
&= \vee[h_p(j), h_p(z), h_p(u)].
\end{aligned}$$

Hence, h_p "Fuzzy Bi-ideal of M". Therefore, $(f, F, \Gamma) \cup (g, G, \Gamma)$ is a FSBI over M. □

Theorem 2.3. *Let (f, F, Γ) and (g, G, Γ) be FSBIs over TGSR M. Then $(f, F, \Gamma) \wedge (g, G, \Gamma)$ is a FSBI over M.*

Proof. From the Definition 3.4, defined in [6], we have $(f, F, \Gamma) \wedge (g, G, \Gamma) = (h, H, \Gamma)$ where $H = FXG, h_d(x) = \min\{f_(x), g_d(x)\}$ for all $d = (a, b) \in FXG$ and $x \in M$. Let $j, m, z, s, u \in M, \alpha, \beta, \gamma, \delta \in \Gamma$, then

$$\begin{aligned}
h_p(j+m) = f_p(j+m) \wedge g_p(j+m) &= \wedge[f_p(j+m), g_p(j+m)] \\
&\geq \wedge[\wedge\{f_p(j), f_p(m)\}, \wedge\{g_p(j), g_p(m)\}] \\
&= \wedge\{\wedge[f_p(j), g_p(j)], \wedge[f_p(m), g_p(m)]\} \\
&= \wedge\{[f_p \wedge g_p](j), [f_p \wedge g_p](m)\} \\
&= \wedge[h_p(f), h_p(m)].
\end{aligned}$$

Now,

$$
\begin{aligned}
h_p(j\alpha m\beta z\gamma s\delta u) &= \wedge\{f_p(j\alpha m\beta z\gamma s\delta u), g_p(j\alpha m\beta z\gamma s\delta u)\} \\
&\geq \wedge\{\vee[f_p(j), f_p(z), f_p(u)], \vee[g_p(j), g_p(z), g_p(u)]\} \\
&= \vee\{\wedge[f_p(j), g_p(j)], \wedge f_p(z), g_p(z), f_p(u), g_p(u)]\} \\
&= \vee\{(f_p \wedge g_p)(j), (f_p \wedge g_p)(z), (f_p \wedge g_p)(u)\} = \vee[h_p(j), h_p(z), h_p(u)].
\end{aligned}
$$

Hence, h_p is a “Fuzzy Bi-ideal of M". Therefore, $(f, F, \Gamma) \wedge (g, G, \Gamma) = (h, H(= F \times G, \Gamma)$ is a FSBI over M. ☐

Theorem 2.4. *Let $(f, F, .)$ and (g, G, Γ) be FSBIs over TGSR M. Then $(f, F, \Gamma) \vee (g, G, \Gamma)$ is a FSBI over M.*

Proof. One can prove as proved in Theorem 2.3, by using the Definition 2.5. in [6]. ☐

Definition 2.3. *A fuzzy set f of a $TGSR$ M is said to be “normal fuzzy ideal” if f is a “fuzzy ideal” of M and $f(0) = 1$.*

Definition 2.4. *Let (f, F, Γ) be fuzzy soft ideal over a TGSR M. Then (f, F, Γ) is said to be “normal fuzzy soft ternary Γ-semiring” if f_a is a “normal fuzzy ideal” of ternary Γ-semiring over M, for all $a \in F$.*

Theorem 2.5. *If (f, F, Γ) is a “fuzzy soft ideal” over a TGSR M and for each $a \in F$, f_a^+ is defined by $f_a^+(x) = f_a(x) + 1 - f_a(0)$ for all $x \in M$ then (f^+, F, Γ) is a "Normal fuzzy soft ideal" on a $TGSR$ of M and (f, F, Γ) is a FSI of (f, F, Γ).*

Proof. Let $j, m, z \in M, \alpha, \beta, \Gamma, a \in F$

$$
\begin{aligned}
f_a^+(j+m) &= f_a(j+m) + 1 - f_(0) \geq \wedge[f_a(j), f_a(m)] + 1 - f_a(0) \\
&\wedge \{f_a(j) + 1 - f_a(0), f_a(m) + 1 - f_a(0)\} \\
&= \wedge\{f_a^+(j), f_a^+(m)\}.
\end{aligned}
$$

Now,

$$
\begin{aligned}
f_a^+(j\alpha m\beta z) &= f_a(j\alpha m\beta z) + 1 - f_a(0) \\
&= \vee[f_a(j), f_a(m), f_a(z)] + 1 - f_a(0) \\
&= \vee[f_a(j) + 1 - f_a(0), f_a(m) + 1 - f_a(0), f_a(z) + 1 - f_a(0)] \\
&= \vee[f_a^+(j), f_a^+(m), f_a^+(z)].
\end{aligned}
$$

Therefore, (f, F, Γ) is a “fuzzy soft ideal” over a TGSR M and (f, F, Γ) is a FSI of (f^{+}, F, Γ). □

By using Definition 3.21, in [6] we can prove the following theorem.

Theorem 2.6. *A fuzzy subset f is a bi-ideal of M if and only if f_a^T, the fuzzy translation of f is a bi-ideal of $TGSR\ M$.*

Proof. let f is a bi-ideal of $TGSR\ M$, $j, m, z, s, u \in M, \alpha, \beta, \gamma, \delta \in \Gamma$. Then

$$\begin{aligned} f_a^T(j+m) = f(j+m) + a = \wedge[f(j), f(m)] + a \\ = \wedge[f(j)+a, f(m)+a] = \wedge[f_a^T(j), f_a^T(m)] \end{aligned}$$

and

$$\begin{aligned} f_a^T(j\alpha m\beta z\gamma s\delta u) = f(j\alpha m\beta z\gamma s\delta u) + a \geq \vee[f(j), f(z, f(u)] + a \\ = \vee[f(j)+a, f(z)+a, f(u)+a] = \vee[f_a^T(j), f_a^T(z), f_a^T(u)]. \end{aligned}$$

Therefore, f_a^T is a bi-ideal of M. converse is obvious. □

Corollary 2.1. *Let M be a $TGSR$. If f is a bi-ideal of $TGSR$, then (f, F, Γ) is "fuzzy translational bi-ideal" over $TGSR\ M$, where $F = \{a/a \in [0, 1 - \sup f(x)/x \in M]\}$.*

Definition 2.5. *Let f be "fuzzy multiplication bi-ideal(FMBI)" of a $TGSR$ M. Then (f, F, Γ) is said to be $FMSBI$(fuzzy multiplication soft Bi-ideal) over M : if f_a is multiplication fuzzy Bi-ideal of TGSR over M for all $a \in F$. Here $F = \{a/a \in [0, 1]\}$.*

Corollary 2.2. *Let f be “fuzzy translational bi- ideal” over a $TGSR\ M$. Then (f, F, Γ) is "fuzzy translational soft bi-ideal" over $TGSR\ M$, where $F = \{a/a \in [0, 1]\}$.*

Theorem 2.7. *Let M be a $TGSR$. Then f is a Bi-ideal of M if and only if f_a^M, the fuzzy multiplication of is a fuzzy Bi-ideal of a $TGSR\ M$.*

Proof. Let f is a Bi-ideal of $M, p, q, r, u, v \in M$, $\alpha, \beta, \gamma, \delta \in \Gamma$. Then,

$$\begin{aligned} f_a^M(p+q) = bf(p+q) \geq b\min(f(p), f(q)) \\ = \min(bf(p), bf(q)) = \min[f_a^M(p), f_a^M(q)] \end{aligned}$$

and

$$\begin{aligned} f_a^M(p\alpha u\beta q\gamma v\delta r) &= bf(p\alpha u\beta q\gamma v\delta r) \\ &\geq b\max(f(p), f(q), f(r)) = \max(bf(p), bf(q), bf(r)) \\ &= \max(f_a^M(p), f_a^M(q), f_a^M(r)). \end{aligned}$$

Therefore, f_a^M is a FBI of M. □

Corollary 2.3. *Let f be "fuzzy bi- ideal" over a $TGSR$ M. Then,(f, F, Γ) is a "multiplicational $FSBI$ over M".*

Theorem 2.8. *Let M be a $TGSR$. Then f is a "fuzzy bi-ideal" of M if and only if f_a^{MT} be a fuzzy magnified translation of f is a "fuzzy bi-ideal" of M.*

Proof. Suppose f is a fuzzy Bi-ideal of M. By Theorem 2.7, this is equivalent to f_a^M is a fuzzy Bi-ideal of M, and further, by Theorem 2.6, is equivalent to f_a^{MT} is a Bi-ideal of M. □

Corollary 2.4. *Let f be "fuzzy magnified translational bi-ideal" (FMTBI) of $TGSR$ M. Then (f, F, Γ) is a $FMTBI$ over M. Where $F = \{a/a \in [0, 1 - \sup\{f(x)/x \in M\}]\}$.*

Theorem 2.9. *Every "fuzzy ideal" of a $TGSR$ M is a "fuzzy bi-ideal" of M.*

Proof. Let f be a "fuzzy ideal" of $M, j, m, z, s, u \in M$, $\alpha, \beta, \gamma, \delta \in \Gamma$. Then

$$\begin{aligned} f(j\alpha m\beta z\gamma s\delta u) &\geq \max f(j, f(m\beta z\gamma s\delta u)) \\ &\geq \max(f(j), f(z), f(m\gamma s\delta u) \\ &\geq \max(f(j), f(z), f(u)). \end{aligned}$$

Therefore, f is a "fuzzy bi-ideal" of M. □

Corollary 2.5. *Let M be a $TGSR$. If (f, F, Γ) is a FSI of M, then (f, F, Γ) is "fuzzy bi- ideal" of over M.*

Theorem 2.10. *Every "fuzzy quasi ideal" of a TGSR M is a "fuzzy bi-ideal" of M.*

Proof. Let f is a fuzzy quasi ideal of TGSR M. Then, $\forall m, j, m, z, s, u \in M$, $\alpha, \beta, \gamma, \delta \in \Gamma$. Then,

$$\begin{aligned} & f(j\alpha m\beta z\gamma s\delta u) \geq (f \circ \chi M \circ \chi M \cap \chi M \circ f \circ \chi M \cap \chi M \circ \chi M \circ f)(j\alpha m\beta z\gamma s\delta u)) \\ \implies & f(j\alpha m\beta z\gamma s\delta u) \geq \max[(f \circ \chi M \circ \chi M(j\alpha m\beta z\gamma s\delta u), (\chi m \circ f \circ \chi m) \\ & (j\alpha m\beta z\gamma s\delta u), (\chi M \circ \chi M \circ f)(j\alpha m\beta z\gamma s\delta u)). \end{aligned}$$

By Definition 2.5, in [3] we have

$$\begin{aligned} & \max\{ \sup_{(a,b,c)\in M_{j\alpha m\beta z\gamma s\delta u}} \max(f(a), \chi M(b), \chi M(c)), \\ & \sup_{(a,b,c)\in M_{j\alpha m\beta z\gamma s\delta u}} \max(\chi M(a), f(b), \chi M(c)), \\ & \sup_{(a,b,c)\in M_{j\alpha m\beta z\gamma s\delta u}} \max(\chi M(a), \chi M(b), f(c)), \} \\ & \geq \max\{\max f(j), \chi M(m\beta z)s, \chi M(s), \\ & \quad \max(\chi M(j\alpha m\beta s), f(z), \chi M(u)), \\ & \quad \max(\chi M(j\alpha m\beta z, \chi m(s), f(u)\} \\ & = \max\{\max(f(j), 1, 1), \max(1, f(z), 1), \max(1, 1, f(u)\} \\ & = \max\{f(j), f(z), f(u)\}. \end{aligned}$$

Hence f is a fuzzy Bi-ideal of M. $\square$

Corollary 2.6. *Let M be a $TGSR$. If (f, F, Γ) is a FSQI over M then (f, F, Γ) is"fuzzy bi- ideal" over M.*

3. Conclusion

In this paper we introduced and studied about "Fuzzy Soft Quasi ideals" and "Fuzzy Soft Bi-Ideals over Ternary Gamma Semirings".

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DEPARTMENT OF MATHEMATICS
KONERU LAKSHMAIAH EDUCATION FOUNDATION
VADDESWARAM, GUNTUR, A.P. INDIA
DEPUTY TRANSPORT COMMISSIONER
GUNTUR(DT), GUNTUR, A.P., INDIA
Email address: meeraprasad.6499@gmail.com

DEPARTMENT OF MATHEMATICS
VSR AND NVR COLLEGE, TENALI, A.P. INDIA
Email address: dmrmaths@gmail.com

DEPARTMENT OF MATHEMATICS
KONERU LAKSHMAIAH EDUCATION FOUNDATION
VADDESWARAM, GUNTUR, A.P. INDIA
Email address: drgsk006@kluniversity.in

DEPARTMENT OF MATHEMATICS, DNR ENGINEERING COLLEGE
BHIMAVARAM, WEST GODAVARI, A.P. INDIA
Email address: bezawadavasantha@gmail.com