



THE SYMMETRIC BAILEY FRAMEWORK FOR KARLSSON-MINTON TO q -BASIC BILATERAL SERIES

Rekha Rani¹, A. K. Shrivastav², Harwinder Kaur³, Sonia Bajaj⁴

^{1,2} Department of Mathematics, MMEC, Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala, Haryana, India.

³ Department of Mathematics, SoS, RIMT University, Mandi Gobindgarh, Punjab, India.

⁴ Department of Mathematics, Chandigarh University, Mohali, India.

Email: ¹rekharanimmu@gmail.com, ²aakkaasshhkumar8888@gmail.com,
³harwinderkaur808@gmail.com, ⁴bajajsonia1501@gmail.com

Corresponding author: A. K. Shrivastav

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Abstract

This article is devoted to deriving certain transformation identities in the theory of q -basic series and q -basic bilateral series. First, we use the symmetric Bailey transform and the Karlsson–Minton summation identity to establish several transformation identities. In the second part, we derive several useful special cases of these transformations. These findings unify and generalize existing results, extending the known results on series and transformation formulas.

Keywords: Bailey's transform, Karlsson-Minton summation formula, q -basic hypergeometric series.

I. Introduction

The study of basic (q -) hypergeometric series and their bilateral analogues forms an essential part of modern analysis and combinatorial theory. These series, typically represented by ${}_r\Phi_s$ and ${}_r\Psi_s$, extend classical hypergeometric functions and appear in partition theory, modular forms, and the theory of mock theta functions. Transformations and summation formulae for such series—particularly those of Heine, Jackson, and Rogers—continue to inspire deep generalizations in q -analysis and mathematical physics [XI–XIII]. Among the most powerful methods in this domain is the Bailey transform and its extensions through well-poised (WP) and symmetric forms. The Bailey pair framework provides a systematic approach for deriving transformation and summation identities for basic and bilateral series, including the famous Rogers–Ramanujan type identities see [III–VII] and [X]. Recent research has shown that symmetric or WP-Bailey pairs provide a unified mechanism

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to generate multi-sum identities and transformation formulae for bilateral q-series [VII]–[IX]. With these recent developments in view, the Karlsson–Minton-type summation theorem, originally formulated for generalized hypergeometric functions, has been extended to the q-domain. These extensions reveal elegant connections between integer parameter shifts and bilateral q-series transformations [I], [II]. Several recent contributions have examined such connections through modified Bailey frameworks, emphasizing the algebraic symmetry underlying q-basic series [III], [VI], [XIII]. The objective of the present work is to establish a symmetric Bailey framework that systematically connects Karlsson–Minton type identities to q-basic bilateral hypergeometric series. The proposed formulation generalizes existing transformation and summation relations, providing new compact bilateral identities and multi-sum representations that encompass results by Shrivastav et al. and collaborators [V], [VI]. [IX] and [X]. Furthermore, the framework facilitates a natural transition between unilateral and bilateral cases, revealing deeper structural symmetry within q-hypergeometric theory. The results also offer potential applications in the analysis of mock theta and quantum q-series [IV].

In 1919, W.N. Bailey established a simple but widely useful transformation known as the Bailey transform. It states,

If

$$\beta_n = \sum_{r=0}^n \alpha_r u_{n-r} v_{n+r} \quad (1.1)$$

and

$$\gamma_n = \sum_{r=n}^{\infty} \delta_r u_{r-n} v_{r+n} = \sum_{r=0}^{\infty} \delta_{r+n} u_r v_{r+2n} \quad (1.2)$$

then under suitable convergence conditions,

$$\sum_{n=0}^{\infty} \alpha_n \gamma_n = \sum_{n=0}^{\infty} \beta_n \delta_n \quad (1.3)$$

where the sequences α_r, u_r, v_r , and δ_r are subject to conditions that ensure the absolute convergence of the infinite series.

Andrews [I] generalized the Bailey transform to the following bilateral form, known as the symmetric bilateral Bailey transform:

If

$$\beta_n = \sum_{r=-n}^n \alpha_r u_{n-r} v_{n+r} \quad (1.4)$$

and

$$\gamma_n = \sum_{r=|n|}^{\infty} \delta_r u_{r-n} v_{r+n} \quad (1.5)$$

then

$$\sum_{n=-\infty}^{\infty} \alpha_n \gamma_n = \sum_{n=0}^{\infty} \beta_n \delta_n \quad (1.6)$$

The identity in (1.6) holds subject to the following conditions:

- (i) the identities (1.4) and (1.5) converge absolutely for all n ;
- (ii) the outer series of $\sum |\alpha_n \gamma_n|$ and $\sum |\beta_n \delta_n|$ converge;
- (iii) the combined double series as $\sum \sum |\alpha_n \delta_r u_{n-r} v_{n+r}|$ and $\sum \sum |\alpha_r \delta_n u_{n-r} v_{n+r}|$ converge absolutely, so that the order of summation may be interchanged;
- (iv) the bilateral tails satisfy the summability conditions $|\alpha_n \gamma_n| \leq M|n|^{-k}$ and $|\beta_n \delta_n| \leq M|n|^{-k}$ for some $M > 0$ and $k < 1$ as $n \rightarrow \pm\infty$

Using the Karlsson-Milton formula [II],

$${}_{k+2}\Phi_{k+1} \left[\begin{matrix} a, b, b_1 q^{m_1}, b_2 q^{m_2}, \dots, b_k q^{m_k}; q, q^{-1} q^{1-m_1-m_2-\dots-m_k} \\ bq, b_1, b_2, b_3, \dots, b_k \end{matrix} \right] = \frac{(a, bq/a; q)_{\infty} (b_1/b; q)_{m_1} \cdots (b_k/b; q)_{m_k} b^{m_1+\dots+m_k}}{(q/a, bq; q)_{\infty} (b_1; q)_{m_1} \cdots (b_k; q)_{m_k}},$$

provided

$$|a^{-1} q^{1-m_1-m_2-\dots-m_k}| < 1. \quad (1.7)$$

II. Notation and Definitions

For a complex number q in the specified range, the q -shifted factorial for integer k is defined as follows:

$$(a; q)_{\infty} = \prod_{i=0}^{\infty} (1 - aq^i) \quad (2.1)$$

$$(a; q)_k = \frac{(a; q)_{\infty}}{(aq^k; q)_{\infty}} \quad (2.2)$$

Using the following condensed notation,

$$(a_1, a_2, a_3, \dots, a_r; q)_k = (a_1; q)_k (a_2; q)_k \cdots (a_r; q)_k \quad (2.3)$$

where k is an integer or infinity.

The generalized basic hypergeometric series is defined as follows:

$${}_r\phi_s \left[\begin{matrix} a_1, a_2, a_3, \dots, a_r; q; z \end{matrix} \middle| \begin{matrix} b_1, b_2, b_3, \dots, b_s \end{matrix} \right] = \sum_{n=0}^{\infty} \frac{(a_1, a_2, a_3, \dots, a_r; q)_n}{(b_1, b_2, b_3, \dots, b_s; q)_n} \left((-1)^n q^{\frac{n(n-1)}{2}} \right)^{1+s-r} z^n \quad (2.4)$$

where $1+s \geq r$ and $|z| < 1$.

The general bilateral hypergeometric series is defined as follows:

$${}_r\Psi_s \left[\begin{matrix} a_1, a_2, a_3, \dots, a_r; q; z \end{matrix} \middle| \begin{matrix} b_1, b_2, b_3, \dots, b_s \end{matrix} \right] = \sum_{n=-\infty}^{\infty} \frac{(a_1, a_2, a_3, \dots, a_r; q)_n}{(b_1, b_2, b_3, \dots, b_s; q)_n} \left((-1)^n q^{\frac{n(n-1)}{2}} \right)^{s-r} z^n,$$

where $s \geq r$ and

$$\left| \frac{b_1 b_2 b_3 \dots b_s}{a_1 a_2 a_3 \dots a_r} \right| < |z| < 1. \quad (2.5)$$

III. Main results

$$\begin{aligned} {}_2\Psi_2 \left(\begin{matrix} b, b_1 q^{m_1} \\ bq, b_1 \end{matrix}; q, q^{-r(m_1+m_2+\dots+m_k)} z^{(m_1+m_2+\dots+m_k)} \right) {}_1\Psi_1 \left(\begin{matrix} b \\ 0 \end{matrix}; q, q^{-r(m_1+m_2+\dots+m_k)} \right) \\ = {}_2\Phi_1 \left(\frac{ab}{bq}; q, z^{(m_1+m_2+\dots+m_k)} \right) \end{aligned} \quad (3.1)$$

$$\begin{aligned} {}_{k+1}\Psi_{k+1} \left[\begin{matrix} b, b_1 q^{m_1}, b_2 q^{m_2}, \dots, b_k q^{m_k} \\ bq, b_1, b_2, \dots, b_k \end{matrix}; q, q^{-M} z^M \right] \\ = {}_{k+2}\Phi_{k+1} \left[\begin{matrix} a, b, b_1 q^{m_1}, b_2 q^{m_2}, \dots, b_k q^{m_k} \\ bq, b_1, b_2, \dots, b_k \end{matrix}; q, q^{-M} z^M \right] \end{aligned} \quad (3.2)$$

IV. Proofs

We begin with the symmetric bilateral Bailey transform:

$$u_r = \frac{1}{(q; q)_r}, \quad v_r = 1$$

&

$$\alpha_r = (-1)^r q^{\frac{r(r+1)}{2}} \frac{(b, b_1 q^{m_1}, b_2 q^{m_2}, \dots, b_k q^{m_k}; q)_r}{(q, bq, b_1, b_2, \dots, b_k; q)_r} q^{-r(m_1+m_2+\dots+m_k)};$$

Substituting u_r , v_r and α_r into the symmetric bilateral Bailey transform (1.4), we obtain

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$$\beta_n = \sum_{r=-n}^n (-1)^r q^{\frac{r(r+1)}{2}} \frac{(b, b_1 q^{m_1}, \dots, b_k q^{m_k}; q)_r}{(q, bq, b_1, \dots, b_k; q)_r} q^{-r(m_1+\dots+m_k)} \frac{1}{(q; q)_{n-r}}.$$

For $r \leq n$, we have $n - r \geq 0$; hence,

$$\frac{1}{(q; q)_{n-r}} = \frac{(q^{1-n+r}; q)_r}{(q; q)_n} (-1)^r q^{nr - \frac{r(r-1)}{2}}.$$

Then

$$\begin{aligned} \beta_n &= \sum_{r=-n}^n (-1)^r q^{\frac{r(r+1)}{2}} \frac{(b, b_1 q^{m_1}, \dots, b_k q^{m_k}; q)_r}{(q, bq, b_1, \dots, b_k; q)_r} q^{-r(m_1+\dots+m_k)} \\ &\times \frac{(q^{1-n+r}; q)_r}{(q; q)_n} (-1)^r q^{nr - \frac{r(r-1)}{2}}. \end{aligned}$$

or,

$$\beta_n = \frac{1}{(q; q)_n} \sum_{r=-n}^n \frac{(b, b_1 q^{m_1}, \dots, b_k q^{m_k}; q)_r}{(q, bq, b_1, \dots, b_k; q)_r} (q^{1-n+r}; q)_r q^{r(n+1)} q^{-r(m_1+\dots+m_k)}.$$

But

$$(q^{1-n+r}; q)_r = \frac{(q^{1-n}; q)_{2r}}{(q^{1-n}; q)_r}$$

by using (2.2), then;

$$\beta_n = \frac{1}{(q; q)_n} \sum_{r=-n}^n \frac{(b, b_1 q^{m_1}, \dots, b_k q^{m_k}; q)_r}{(q, bq, b_1, \dots, b_k; q)_r} \frac{(q^{1-n}; q)_{2r}}{(q^{1-n}; q)_r} q^{r(n+1)} q^{-r(m_1+\dots+m_k)}. \quad (4.1)$$

Next, substituting

$$u_r = \frac{1}{(q; q)_r}, \quad v_r = 1$$

&

$$\delta_r = (a; q)_r z^r \left(\frac{q^{1-r}}{q}; q \right);$$

into the symmetric bilateral Bailey transform (1.5), we obtain

$$\gamma_n = \sum_{r=|n|}^{\infty} \delta_r u_{r-n} v_{r+n} = \sum_{r=|n|}^{\infty} (a; q)_r z^r \left(\frac{q^{1-r}}{q}; q \right) \frac{1}{(q; q)_{r-n}}.$$

For $r \geq |n|$, we have $r - n \geq 0$, so

$$\frac{1}{(q; q)_{r-n}} = \frac{(q^{1-r+n}; q)_n}{(q; q)_r} (-1)^n q^{n(r-n) - \frac{n(n-1)}{2}}.$$

We also simplify

$$\left(\frac{q^{1-r}}{q}; q \right) = \frac{(q^{-r}; q)_{\infty}}{(q^{-r+1}; q)_{\infty}}.$$

Using the negative-index identity,

$$(q^{-r}; q)_{\infty} = \frac{1}{(q; q)_r} (-1)^r q^{\frac{r(r+1)}{2}},$$

we obtain

$$\left(\frac{q^{1-r}}{q}; q \right) = \frac{(q^{-r}; q)_{\infty}}{(q^{-r+1}; q)_{\infty}} = q^r \frac{(q; q)_{r-1}}{(q; q)_r} = \frac{q^r}{1 - q^r}.$$

Substituting for γ_n , we get

$$\gamma_n = \sum_{r=|n|}^{\infty} \frac{(a; q)_r z^r q^r}{1 - q^r} \frac{(q^{1-r+n}; q)_n}{(q; q)_r} (-1)^n q^{n(r-n) - \frac{n(n-1)}{2}}.$$

or,

$$\gamma_n = (-1)^n q^{-n^2 - \frac{n(n-1)}{2}} \sum_{r=|n|}^{\infty} \frac{(a; q)_r}{(q; q)_r} \frac{(q^{1-r+n}; q)_n}{1 - q^r} z^r q^{r(n+1)}.$$

(4.2)

Next, substituting (4.1) and (4.2) into (1.6), we obtain

$$\begin{aligned}
 & \sum_{n=-\infty}^{\infty} \frac{(-1)^n q^{\frac{n(n+1)}{2}} (b, b_1 q^{m_1}, b_2 q^{m_2}, \dots, b_k q^{m_k}; q)_n}{(q, bq, b_1, b_2, \dots, b_k; q)_n} \\
 & \times q^{-n(m_1+m_2+\dots+m_k)} \sum_{r=|n|}^{\infty} \frac{(\alpha; q)_r z^r \left(\frac{q^{1-r}}{q}; q\right) (-q)^n q^{nr}}{(q; q)_r q^{\frac{n(n+1)}{2}}} \\
 & = \sum_{r=-n}^n (-1)^r q^{\frac{r(r+1)}{2}} \frac{(b, b_1 q^{m_1}, b_2 q^{m_2}, \dots, b_k q^{m_k}; q)_r q^{nr}}{(q, bq, b_1, b_2, \dots, b_k; q)_r (q; q)_n q^{\frac{r(r+1)}{2}}} \\
 & \times \sum_{n=0}^{\infty} (\alpha; q)_n z^n (-q)^r \left(\frac{q^{1-r}}{q}; q\right) q^{-r(m_1+m_2+\dots+m_k)}
 \end{aligned}$$

Thus, after simplification and using (2.4) and (2.5), we derive result (3.1) as follows:

$$\begin{aligned}
 & {}_2\Psi_2 \left(\begin{matrix} b, b_1 q^{m_1} \\ bq, b_1 \end{matrix}; q, q^{-r(m_1+\dots+m_k)} z^{r(m_1+\dots+m_k)} \right) {}_1\Psi_1 \left(\begin{matrix} b \\ 0 \end{matrix}; q, q^{-r(m_1+\dots+m_k)} \right) \\
 & = {}_2\Phi_1 \left(\frac{a}{bq}; q, z^{r(m_1+\dots+m_k)} \right).
 \end{aligned} \tag{4.3}$$

Furthermore substituting $M=(m_1+m_2+\dots+m_k)$ in (4.3), we impose the following combined restrictions, which arise from the bilateral series (2.5), the intermediate ${}_1\Psi_1$ series, and the Karlsson–Minton condition (1.7):

- (i) $|q| < 1$;
- (ii) $|z| < 1$;
- (iii) $M=(m_1+m_2+\dots+m_k) \geq 0, m_i \in \mathbb{Z}_{<0}$;
- (iv) $|q^{1-m_1}| < |q^{rM} z^{rM}| < 1, \text{ for all } r \geq 0$;
- (v) $|a| > |q|^{1-M}$;
- (vi) $|q| < |z|$;
- (vii) no denominator q -Pochhammer factor vanishes.

we obtain

$$\begin{aligned}
 & {}_{k+1}\Psi_{k+1} \left(\begin{matrix} b, b_1 q^{m_1}, b_2 q^{m_2}, \dots, b_k q^{m_k} \\ bq, b_1, b_2, \dots, b_k \end{matrix}; q, q^{-M} z^M \right) \\
 & = {}_{k+2}\Phi_{k+1} \left(\begin{matrix} a, b, b_1 q^{m_1}, b_2 q^{m_2}, \dots, b_k q^{m_k} \\ bq, b_1, b_2, \dots, b_k \end{matrix}; q, q^{-M} z^M \right)
 \end{aligned} \tag{4.4}$$

where $M=(m_1+m_2+\dots+m_k)$ and $|z|<1, |q|<1$.

This result provides an identity connecting the bilateral basic hypergeometric series ${}_{k+1}\Psi_{k+1}$ to the basic hypergeometric series ${}_{k+2}\Phi_{k+1}$.

V. Special cases

Here, we derive several special cases of the result established in the preceding section.

- (i) Substituting $b=q$ into main result (4.3) and summing with identities (2.1)-(2.5), we obtain

$${}_2\Psi_2\left(\begin{matrix} q, b_1q^{m_1} \\ q^2, b_1 \end{matrix}; q, q^{-rM}z^{rM}\right) \frac{q(1-q^{rM-1})}{(1-q^{rM})^2} (q; q)_\infty^2 = {}_2\Phi_1\left(\begin{matrix} a, aq \\ q^2 \end{matrix}; q, z^{rM}\right)$$

where $M=(m_1+m_2+\dots+m_k)$.

(5.1)

- (ii) Substituting $a=bq$ into the main result (4.4), we obtain

$$\begin{aligned} & {}_{k+1}\Psi_{k+1}\left(\begin{matrix} b, b_1q^{m_1}, b_2q^{m_2}, \dots, b_kq^{m_k} \\ bq, b_1, b_2, \dots, b_k \end{matrix}; q, q^{-M}z^M\right) \\ &= {}_{k+1}\Phi_k\left(\begin{matrix} b, b_1q^{m_1}, b_2q^{m_2}, \dots, b_kq^{m_k} \\ b_1, b_2, \dots, b_k \end{matrix}; q, q^{-M}z^M\right) \end{aligned}$$

(5.2)

where

$$|z|<1, |q|<1, M=(m_1+m_2+\dots+m_k)$$

If $z \rightarrow 1$, (5.2) yields

$$\begin{aligned} & {}_{k+1}\Psi_{k+1}\left(\begin{matrix} b, b_1q^{m_1}, b_2q^{m_2}, \dots, b_kq^{m_k} \\ bq, b_1, b_2, \dots, b_k \end{matrix}; q, q^{-M}\right) \\ &= {}_{k+1}\Phi_k\left(\begin{matrix} b, b_1q^{m_1}, b_2q^{m_2}, \dots, b_kq^{m_k} \\ b_1, b_2, \dots, b_k \end{matrix}; q, q^{-M}\right) \end{aligned}$$

(5.3)

where $M=(m_1+m_2+\dots+m_k)$.

- (iii) Again, taking Z/α for z , and then letting $\alpha \rightarrow \infty$ in equation (4.3), we obtain

$${}_2\Psi_2\left(\begin{matrix} b, b_1q^{m_1} \\ bq, b_1 \end{matrix}; q, q^{-r(m_1+\dots+m_k)}Z^{r(m_1+\dots+m_k)}\right) {}_1\Psi_1\left(\begin{matrix} b \\ 0 \end{matrix}; q, q^{-r(m_1+\dots+m_k)}\right)$$

$$= {}_2\phi_1\left(\begin{matrix} a, b \\ bq \end{matrix}; q, Z^{r(m_1+\dots+m_k)}\right) \quad (5.4)$$

Next, assuming the nontrivial case as $rM=1$ in (5.4);

$${}_2\psi_2\left(\begin{matrix} b, b_1q^{m_1} \\ bq, b_1 \end{matrix}; q, q^{-1}Z\right) {}_1\psi_1\left(\begin{matrix} b \\ 0 \end{matrix}; q, q^{-1}\right) = {}_1\phi_1\left(\begin{matrix} b \\ bq \end{matrix}; q, Z\right) \quad (5.5)$$

Then, for $b=q$ in (5.5), this reduces to;

$${}_2\psi_2\left(\begin{matrix} b, b_1q^{m_1} \\ bq, b_1 \end{matrix}; q, q^{-1}Z\right) {}_1\psi_1\left(\begin{matrix} b \\ 0 \end{matrix}; q, q^{-1}\right) = \sum_{n=0}^{\infty} \frac{Z^n}{(q^2; q)_n} \quad (5.6)$$

VI. Conclusion

This work demonstrates that applying the symmetrical Bailey transform together with the Karlsson-Minton summation identity, several new transformation formulas for q -basic and q -basic bilateral hypergeometric series can be obtained. In particular, when the parameters are $b=q$ and $a=bq$, and the nontrivial condition $r_M=1$, the results simplify to compact forms that include a number of known identities as special cases. These particular reductions not only validate the derived general formulas but also demonstrate their applicability in extending classical results in the theory of q -series.

Conflict of Interest:

The authors declare that there was no relevant conflict of interest regarding this paper.

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