

## EXISTENCE RESULTS FOR NONLINEAR SECOND-ORDER $q$ -DIFFERENCE EQUATIONS WITH $q$ -INTEGRAL BOUNDARY CONDITIONS

THAMONWAN SAENGNGAMMONGKHL, BUNJONG KAEWWISETKUL AND  
THANIN SITTHIWIRATTHAM

**Abstract.** In this paper, we present some new existence and uniqueness results for the  $q$ -integral boundary value problem of nonlinear  $q$ -difference equation. Our results are based on Banach's contraction principle and Krasnowelskii's fixed point theorem. An example is given to illustrate the advantage of our results.

*Mathematics subject classification (2010):* 39A05, 39A13.

*Keywords and phrases:* existence,  $q$ -derivative,  $q$ -integral,  $q$ -difference equation.

### REFERENCES

- [1] F.H. JACKSON, *On  $q$ -difference equations*, American J. Math., **32** (1910), 305–314.
- [2] R.D. CARMICHAEL, *The general theory of linear  $q$ -difference equations*, American J. Math., **34** (1912), 147–168.
- [3] T.E. MASON, *On properties of the solutions of linear  $q$ -difference equations with entire function coefficients*, American J. Math., **37** (1915), 439–444.
- [4] C.R. ADAMS, *On the linear ordinary  $q$ -difference equation*, American Math. Ser. II., **30** (1929), 195–205.
- [5] W.J. TRITZINSKY, *Analytic theory of linear  $q$ -diffece equations*, Acta Mathematica., **62**, 1 (1933), 167–226.
- [6] V. KAC, P. CHEUNG, *Quantum Calculus*, Springer, New York, 2002.
- [7] G. BANGEREZAKO, *Variational  $q$ -calculus*, J. Math. Anal. Appl., **289** (2004), 650–665.
- [8] A. DOBROGOWSKA, A. ODZIEJEWICZ, *Second order  $q$ -difference equations solvable by factorization method*, J. Comput. Appl. Math., **193** (2006), 319–346.
- [9] T. ERNST, *A new notation for  $q$ -calculus and a new  $q$ -Taylor formula*, U.U.D.M. Report, 1999:25, ISSN 1101-3591, Department of Mathematics, Uppsala University, 1999.
- [10] R. FLOREANINI, L. VINET,  *$q$ -gamma and  $q$ -beta functions in quantum algebra representation theory*, J. Comput. Appl. Math., **68** (1996), 57–68.
- [11] M.E.H. ISMAIL, P. SIMEONOV,  *$q$ -difference operators for orthogonal polynomials*, J. Comput. Appl. Math., **233** (2009), 749–761.
- [12] M. EL-SHAHED, H.A. HASSAN, *Positive solutions of  $q$ -difference equation*, Proc. Amer. Math. Soc., **138** (2010), 1733–1738.
- [13] B. AHMAD, *Boundary value problems for nonlinear third-order  $q$ -difference equations*, Electron. J. Diff. Equ., **94** (2011), 1–7.
- [14] B. AHMAD, A. ALSAEDI, S.K. NTOUYAS, *A study of second-order  $q$ -difference equations with boundary conditions*, Adv. Diff. Equ., **2012**, Article No.35.
- [15] B. AHMAD, S.K. NTOUYAS, I.K. PURNARAS, *Existence results for nonlinear  $q$ -difference equations with nonlocal boundary conditions*, Commun. Appl. Nonlinear Anal., **19** (2012), 59–72.
- [16] B. AHMAD, J.J. NIETO, *On nonlocal boundary value problems of nonlinear  $q$ -difference equations*, Adv. Diff. Equ., **2012**, Article No.81.

- [17] B. AHMAD, S.K. NTOUYAS, *Boundary value problems for  $q$ -difference inclusions*, Abst. Appl. Anal., **2011**, Article ID 292860, 15 pages.
- [18] C. YU, J. WANG, *Existence of solutions for nonlinear second-order  $q$ -difference equations with first-order  $q$ -derivatives*, Adv. Differ. Equ., **2013**, Article No.124.
- [19] N. PONGARM, S. ASAWASAMRIT, J. TARIBOON, *Sequential derivatives of nonlinear  $q$ -difference equations with three-point  $q$ -integral boundary conditions*, J. Appl. Math., **2013**, Article ID 605169, 9 pages.
- [20] T. SITTHIWIRATTHAM, J. TARIBOON, S.K. NTOUYAS, *Three-point boundary value problems of nonlinear second-order  $q$ -difference equations involving different numbers of  $q$* , J. Appl. Math., **2013**, Article ID 763786, 12 pages.
- [21] N. PATANARAPRERT, T. SITTHIWIRATTHAM, *Existence results of sequential derivatives of nonlinear quantum difference equations with a new class of three-point boundary value problems conditions*, J. Comput. Anal. Appl., **18** (2015), 844–856.
- [22] M.A. KRASNOSELSKII, *Two remarks on the method of successive approximations*, Uspekhi Mat. Nauk, **10** (1955), 123–127.