Annual Research & Review in Biology

21(3): 1-9, 2017; Article no.ARRB.37622
ISSN: 2347-565X, NLM ID: 101632869

Sustainable Water Management for Potato Production in Drought Prone Areas in Bangladesh

Md. Akhter-Ul-Alam[1], Zannatul Ferdous[1,2*], Khairul Islam[1], Most. Ummay Salma Khatun[1], Md. Babul Akter[3], Ummay Kulsum Laily[1], Mazharul Anwar[1] and Khakon Kumar Sarker[4]

[1]On-Farm Research Division, Bangladesh Agricultural Research Institute, Agricultural Research Station, Alamnagar, Rangpur, Bangladesh.
[2]Department of Food, Agriculture and Bioresources, School of Environment, Resources and Development, Asian Institute of Technology, Pathumthani 12120, Thailand.
[3]Crop Physiology Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh.
[4]Irrigation and Water Management Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh.

Authors' contributions

This work was carried out in collaboration between all authors. Authors MAUA, MUSK and KKS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors ZF, KI and MBA managed the analyses of the study and improved the manuscript. Authors UKL and MA managed the literature searches and improved the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ARRB/2017/37622
Editor(s):
(1) George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
Reviewers:
(1) Ahmed Karmaoui, Southern Center for Culture and Sciences, Morocco.
(2) Miguel Aguilar Cortes, Universidad Autónoma del Estado de Morelos, Mexico.
Complete Peer review History: http://www.sciencedomain.org/review-history/22411

Original Research Article

Received 23rd October 2017
Accepted 24th November 2017
Published 22nd December 2017

ABSTRACT

Water management practices are an essential component of modern intensive potato (*Solanum tuberosum*) production. A farmer's field based experiment was conducted in Multi Location Testing (MLT) site, Khalashpir, Rangpur under On-Farm Research Division, Rangpur during two years of 2014-2015 and 2015-2016 to find out the effect of irrigation scheduling with crop growth stages over conventional practice in potato. Four irrigation treatments were studied under the trial and the

**Corresponding author: E-mail: zferdous80@bari.gov.bd;*

treatments were, I_1= Farmers practice, I_2= Irrigation at stolonization and tuberization stages, I_3= Irrigation at stolonization and bulking stages and I_4= Irrigation at stolonization, tuberization and bulking stages. The highest yield was recorded in I_3 (23.11 tha^{-1} and 20.27 tha^{-1}) whereas lowest was in I_1 (19.11 tha^{-1} and 17.13 tha^{-1}). The highest gross margin was recorded in I_3 (BDT.74610 ha^{-1} and BDT. 68210 ha^{-1}) and lowest was in I_1 (BDT. 36660 ha^{-1} and BDT. 28060 ha^{-1}). Water savings can also be attained by allowing higher soil water depletion toward the ripening period so that all available stored water in the root zone is used by the crop. This practice may also hasten maturity. Correct timing of irrigation may save 1 to 3 irrigation applications as well as also save the production cost of the farmers.

Keywords: Judicial water use; drought management; sustainable potato production.

1. INTRODUCTION

Irrigation development is an important means for achieving food self-sufficiency in many countries in the world, including Bangladesh, in order to address the main challenge caused by food insecurity and water scarcity [1]. Many literatures also agree that development of irrigation can be taken as a strategy for reducing poverty and ensuring food security in the world poorest regions [1-3].

There are several strategies to improve the world food production under water scarcity [4]. Potato (*Solanum tuberosum* L.) is the fourth most important cultivated food crop and is believed to contribute significantly to sustain future global food security [5,6]. The crop has a high-water demand and is sensitive to drought stress, particularly during the tuber bulking stage [7]. Among the vulnerable countries due to the effects of climate change Bangladesh holds top position. The overall impacts of climate change will unstable agricultural productivity in a large scale. All the farmers are efficient regarding their effort in crop production. Total crop season are grouped into three classes namely; Rabi, Kharif-I and Kharif-II. In Rabi period i.e during winter diversification of crop more than kharif. Boro rice is grown normally at large extent during late Rabi to early Khraif. Production of Boro rice requires two to seven times more irrigation than other Rabi crops due to evapotranspiration, seepage and percolation. Sustainable crop production relates with optimum resource management based on input availability [8,9]. In northern part of Bangladesh Potato-Maize-Transplant aman rice turning into a major cropping pattern now-a-days [10,11].

Potato is the number one vegetable crop of Bangladesh both in terms of area and production [12]. It alone constitutes more than 50% of the total annual vegetable production in the country [10]. In Bangladesh it is consumed generally as vegetable and hence potato is a crop of great economic significance in national agriculture. Many modern potato varieties are commercially grown in Bangladesh at present. In the northern parts of Bangladesh modern potato varieties are getting popularity among farmers which possess some excellent characteristics like high yielding, resistant to insects and pests and diseases. These are also very palatable in taste. The yield of these varieties can be improved to a great extent by optimum application of supplemental irrigation [13]. It is well known that soil water status is one of the most important factors affecting the bioavailability of different nutrients in the soil. It has been shown that irrigation management can influence the transformation of organic compounds to inorganic nutrients in the soil [14,15]. Maintenance of a relatively high soil water content by frequent irrigation often led to higher bioavailability of plant nutrient [16]. In addition, soil drying and wetting cycles have been reported to influence on the soil nutrient bioavailability significantly [17].

In Bangladesh potato is grown during the driest months of the year. The soil moisture during the growing period of potato crop is one of the main limiting factors for its successful cultivation; Mulubrehan K. and T.G. Gebretsadikan [18] noted that better results may be achieved from frequent and liberal application of water. Judicious utilization of water is very important [19]. Water requirement of crops depends on the rate of evapotranspiration which depends on climatic conditions, soil type and physiology [13,20]. The water requirement of potato plant at different phases of its growth is different. The most sensitive phases are the stolonization and beginning of tuberization phases. At these phases, the water requirement is the greatest.

Sufficient amount of soil moisture is also necessary at tuber bulking stage for proper development of tubers [18]. The frequency of irrigation at different stages of growth and development of potato determines the yield and quality of potato Sun et al. [21]. Production of potato hinders due to many abiotic stresses among them water stress most critical one. Optimum production can be ensured by proper amount of irrigation water supply at different growth stages and status of soil moisture level. Required amount of irrigation water can be calculated by different techniques. Therefore, this study was undertaken to investigate the effect of different amount of irrigation water on yield of potato.

Therefore, water-saving measures that can enhance both potato yield and quality play an important role. The aim of effective and efficient watering of a growing crop is to replenish depleted soil moisture at a given time to avoid physiological water stress in the growing plants. The determination of irrigating water amounts required for crop are important for estimating the quantity of water for plant growth, in order to have better water saving and water management. Therefore, this study was undertaken to investigate the effect of different amount of irrigation water on yield and yield characteristics of potato.

The specific objectives of this study were to develop suitable water management practices based on major cropping patterns in drought prone areas and to optimize the crops yield with limited supply of irrigation water under climate change condition in Bangladesh.

2. MATERIALS AND METHODS

2.1 Plant Material

Seed of potato cultivar “Cardinal” was collected from Breeder Seed production Farm, Debigonj, Panchagar, Bangladesh Agricultural Research Institute, Bangladesh.

Meteorological data’s such as minimum and maximum temperature, rainfall were collected from nearby weather station to determine reference crop evapotranspiration (Fig. 1). The rainfall received during the growing season was almost 0 mm. The mean monthly rainfall, maximum and minimum temperature distribution for the study year is explained in Fig. 1. Comparison of those graphs explicitly shows that there was no any source of moisture other than irrigation for the study period.

2.2 Site Description

The experiment was carried out in the farmer’s field in the village of Khalashpir, Pirganj subdistrict, Rangpur distrcit under Multi-location Testing (MLT) site under Bangladesh Agricultural Research Institute (BARI) during two consecutive years of 2014-2015 and 2015-2016.

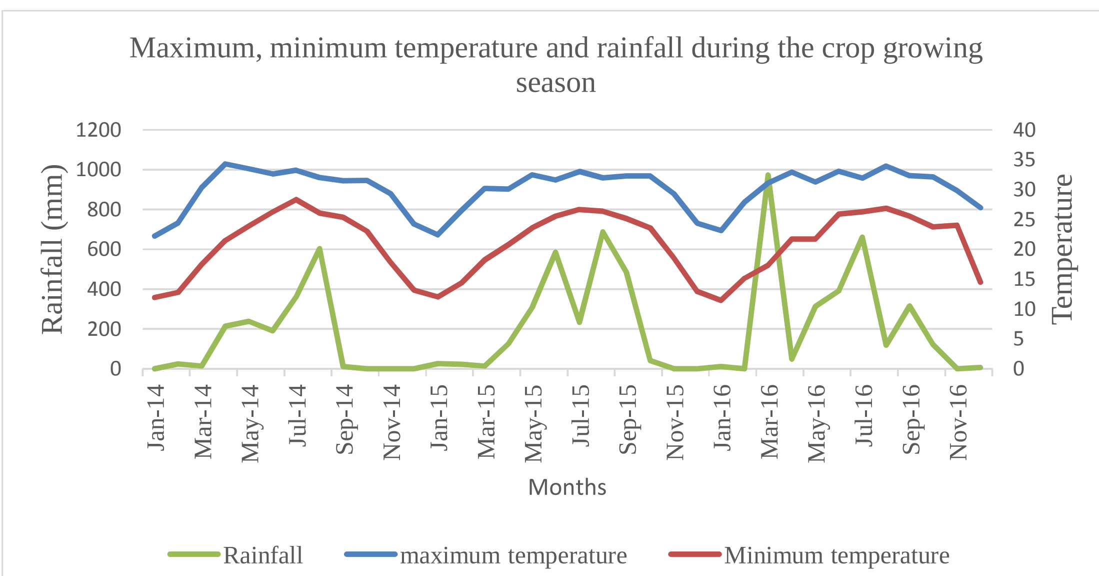

Fig. 1. Maximum, minimum temperature and rainfall during the crop growing season

Table 1. Initial soil status at Multi-Location Testing (MLT) site, Pirgonj, Rangpur

	pH	OM (%)	Total N (%)	P	K	S	Zn	B
				µg/g soil				
Value	6.2	0.93	0.03	43.8	0.45	5.20	0.88	0.26
Interpretation	Slightly acidic	VL	VL	VH	H	VL	L	L

OM=Organic matter, VL=Very low, H=High, L=low

The experimental area is situated between 25°40' and 26°12.5' North latitude and 88°39' and 88°45' East longitude. The land topography is medium high land and the soil belongs to the North Eastern Barind Tract under Agro Ecological Zone (AEZ) 27. The experimental land was quite uniform and soil analyses were conducted to ascertain soil fertility status before planting (Table 1).

Texturally the soil of the experimental field is silty loam having 49.64 per cent sand, 30.00 per cent silt and 20.36 per cent clay. The average bulk density of the soil is 1.43 gm/cc. The soil is slightly acidic with pH value 5.34 having organic matter 1.155%.

2.3 Experimental Details

Experiment was replicated thrice in a randomized complete block design (RCBD) with three dispersed replications [22,23]. The plot size was 6 m × 5 m.

2.4 Crop Management

The entire amount of cowdung manure was applied 4 days before final land preparation. The whole of P, K, S, Mg, Zn, B and 1/3 of N were applied during final land preparation. The rest of N was applied in two equal installments as top dress at 25 and 50 Days after emergence (DAE). One weeding was done at 25 DAE. The crop was planted on 25-29 November in both the years. Preventive measures were taken to control insect and diseases applying appropriate insecticides and fungicides. Carbofuran 5 G at the rate of 15 kg ha^{-1} was applied in furrows (depth 5-6 cm) to control cut worm. To control late blight and aphid, Mancozeb and Malathion applied at the rate of 2 kg and 1 L, respectively. Crops were harvested at 90 Days after planting (DAS) after proper tuber maturing. Potatoes complete its life cycle through four stages which are stolonization stage (35 DAP), tuberization stage (45 DAP), bulking stage (60 DAP) and ripening stage (80 DAP).

2.4.1 Data collection and statistical analysis

After maturing randomly 5 plants were harvested to record the yield and yield contributing characters of potato. Fresh tuber yield was harvested from randomly pre-selected central areas (about 9 m^{-2}) of each plot and converted into tons per hectare (t ha^{-1}). Mean data was analyzed statistically and was carried out to analysis of variance (ANOVA) using the MSTAT-C. Further statistical validity of the differences among treatment means was estimated using the least significant difference (LSD) comparison method.

2.4.2 Economic and marginal analysis

Benefit-cost analysis was conducted to estimate the economic feasibility of potato crop. The production costs of potato included the cost of field preparation, seed, planting, irrigation, fertilizers, crop protection measures and harvesting. The gross income was estimated using the prevailing average market prices for the tuber yield of potato in Bangladesh. Net income was calculated by subtracting total expenditure from the gross income [24]. Marginal analysis was carried out on the basis of variable costs and prevailing market prices of potato [22,23].

3. RESULTS

3.1 Growth Characters as Influenced by Irrigation Regimes

3.1.1 Plant height

The growth of potato plant as evident from plant height was significantly influenced by different irrigation treatments (Tables 2 & 3). In both years, the tallest plant height (54.69 cm and 54.97 cm) was produced from the significant differences were observed among irrigation treatments of which I_3 treatment i.e irrigations at stolonization and bulking stage; whereas in both year the shortest plant height (52.67 cm and 52.95 cm) was recorded in the I_2 treatment i.e irrigations at stolonization and tuberization during 2014-15 and 2015-16 respectively.

3.1.2 Number of stems hill^{-1}

The stem number hill^{-1} was varied significantly with different irrigation treatments. The maximum number of stem hill^{-1} was counted in treatment I_3 (4.41 and 4.40) where crop was irrigated during stolonization and bulking stage followed by treatment I_4 (4.06 and 4.12) with three times of irrigation and the stages was stolonization, tuberization and bulking stage. The lowest number of hill was counted from farmers practice I_1 (3.48), where five times irrigation was done.

3.2 Yield and Yield Contributing Characters-as Influenced by Irrigation Regimes

3.2.1 Number of tubers hill^{-1}

Number of tubers was counted randomly from each treatment and there was significant variation was observed among them. The maximum numbers of tuber hill^{-1} was counted from the third irrigation treatment I_3 (7.05 and 7.42) where crop was irrigated during stolonization and bulking stage. The minimum number of tuber per hill was counted from the I_1 treatment (5.82 and 5.98) during both the year. The I_2 treatment (irrigation at stolonization and tuberization stages) and I_4 (irrigation at stolonization, tuberization and bulking stages) showed statistically similar number of tuber hill^{-1}.

3.2.2 Average tuber weight plant^{-1}

The weight of tubers plant^{-1} was significantly influenced by number of irrigation added in the experimental plot (Tables 2 & 3). It was found that among the irrigation treatments statistically highest (358.2 g) tuber yield hill^{-1} was attained with I_3 whereas the lowest (271.70 g) was with I_1 during 2014-15. In 2015-2016 similar data trend was observed. The maximum tuber weight plant^{-1} was recorded from I_3 (363.3 g) and the lowest was in the I_1 (265.0 g). Irrigation during stolonization and bulking stage maximize the tuber weight per plant. Fandika et al. [25] also reported that proper irrigation enhanced the average tuber weight, fresh total tuber yield.

3.2.3 Average length of tuber (cm)

There was significant difference among the treatments regarding length of potato. The highest length of potato was recorded in I_3 (7.75 cm) with irrigation during stolonization and bulking stage which was followed by I_2 (7.27 cm) where crop was irrigated during stolonization and tuberization. The lowest potato length was measured in I_1 i.e farmers practice (6.48 cm) with additional three time's irrigation during 2014-15. In 2015-2016 the highest tuber length was recorded from the I_3 (7.75 cm) treatment and the lowest was from I_1 (6.48 cm) treatment.

3.2.4 Average diameter of tuber (cm)

Potato diameter data was recorded from the selected potato plants and there was no statistical difference among treatments. Numerically the highest potato tuber diameter was recorded from I_3 treatment (16.08 cm and 15.65 cm) i.e irrigation provided during stolonization and bulking. The lowest tuber diameter (15.12 cm and14.90 cm) was recorded in farmers treated plot I_1.

3.2.5 Tuber yield (t ha^{-1})

The result displayed in Table 2 indicated that yield of potato was significantly ($p < 0.05$) affected by water regimes. Total yield of potato tuber was recorded from the plot yield according to the treatment. The main effects of treatment for tuber yield per hectare showed significant variation and ranged from 19.99 to 23.11 tha^{-1} in 2014-15 and 17.13 to 20.27 tha^{-1} in 2015-16 (Table 3). Among the treatments, tuber yield was highest in I_3 treatment (23.11) while I_1 treatment (19.99) produced the lowest and yield was statistically similar between I_2 and I_4 treatments (21.81 and 21.42 tha^{-1}) during 2014-15. Next year the highest tuber yield was recorded in I_3 (20.27 tha^{-1}) and lowest was in I_1 (17.13 tha^{-1}).

3.3 Economic Analysis

The economic benefits were much higher from plots with Irrigation at stolonization and bulking stages and Irrigation at stolonization, tuberization and bulking stages compare with farmers practice (Tables 4 & 5). The cost of production was estimated based on the production elements in Tables 4 & 5. Cost and return analysis of the results from Khalashpir, Pirgonj, revealed that the highest gross return (BDT. 231100 ha^{-1} and BDT.202700 ha^{-1}) and Gross margin (BDT. 74610 ha^{-1} and BDT. 68210 ha^{-1}) was recorded in Irrigation at stolonization and bulking stages respectively 2014-2015 and 2015-2016 whereas the lowest gross return (BDT.199900 ha^{-1} and BDT. 171300 ha^{-1}) and gross margin (BDT. 36660 ha^{-1} and BDT. 28060 ha^{-1}) was found in farmers practice.

Table 2. Yield and yield attributes of potato obtained different level of irrigation during Rabi season of 2014-2015 at MLT site, Khalashpir, Pirgonj

Treatments	Plant height (cm)		Stem hill^{-1} (Number)		Number of tuber hill^{-1}		Average weight of tuber plant^{-1} (g)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
I_1	52.95	53.77	3.51	3.48	5.82	5.98	271.7	265.0
I_2	52.67	52.95	4.04	3.95	6.39	6.75	323.3	321.7
I_3	54.69	54.97	4.41	4.40	7.05	7.42	358.2	363.3
I_4	54.04	54.50	4.06	4.12	6.55	6.92	329.4	332.5
CV	2.30	3.71	3.75	9.03	3.60	5.16	3.18	4.29
LSD	2.463	2.47	0.30	0.44	0.46	0.43	20.43	16.91
Level of significance	**	**	**	**	**	**	**	**

*** Significant at P≤ 0.01, means were separated by using the least significant difference (LSD) method*
I_1= Farmers practice, I_2= Irrigation at stolonization and tuberization stages, I_3= Irrigation at stolonization and bulking stages and I_4= Irrigation at stolonization, tuberization and bulking stages

Table 3. Yield and yield attributes of potato obtained different level of irrigation during Rabi season of 2015-2016 at MLT site, Khalashpir, Pirgonj

Treatments	Average length of tuber (cm)		Average Diameter of tuber (cm)		Yield (t ha^{-1})	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
I_1	6.58	6.48	15.22	14.90	19.99	17.13
I_2	7.27	7.20	15.57	15.37	21.81	18.93
I_3	7.66	7.75	16.08	15.65	23.11	20.27
I_4	7.06	6.95	15.39	15.50	21.42	18.23
CV	3.62	4.30	3.07	4.52	1.75	2.03
LSD	0.52	0.38	0.91	0.85	0.58	0.42
Level of significance	**	**	NS	NS	**	**

*** Significant at P≤ 0.01, means were separated by using the least significant difference (LSD) method, NS=Non-significant, I_1= Farmers practice, I_2= Irrigation at stolonization and tuberization stages, I_3= Irrigation at stolonization and bulking stages and I_4= Irrigation at stolonization, tuberization and bulking stages*

Table 4. Cost and return analysis obtained from the experimentation conducted at MLT site, Khalashpir, Pirgonj during Rabi season 2014-15

Treatment	Gross return (BDT. ha^{-1})	TVC (BDT. ha^{-1})	Gross margin (BDT. ha^{-1})
I_1	199900	163240	36660
I_2	218100	156490	61610
I_3	231100	156490	74610
I_4	214200	158740	55460

Transplanted aman rice=T. aman, 80 (BDT.)= 1 $USD,TVC=Total variable cost, Market price: Potato 10 BDT. kg^{-1}

Table 5. Cost and return analysis obtained from the experimentation conducted at MLT site, Khalashpir, Pirgonj during Rabi season 2015-16

Treatment	Gross return (BDT. ha^{-1})	TVC (BDT. ha^{-1})	Gross margin (BDT. ha^{-1})
I_1	171300	143240	28060
I_2	189300	134490	54810
I_3	202700	134490	68210
I_4	182300	138740	43560

Transplanted aman rice=T. aman, 80 (BDT.)= 1 $USD,TVC=Total variable cost, Market price: Potato 10 BDT. kg^{-1}

4. DISCUSSION

Our findings indicate that plots with Irrigation at stolonization and bulking stages and Irrigation at stolonization, tuberization and bulking stages in particular, is more profitable and save more water than farmers practice (Tables 4 & 5).The importance of irrigation for tuber production has been well documented (Rosen et al. [26]); some studies have demonstrated that proper irrigation supply could enhance the tuber weight [25] and increase the tuber yield [21,27], in good agreement with our findings. Proper irrigation enhanced the average tuber weight, fresh total tuber yield and marketable tuber yield by 51%, 33% and 55% [25]. Farmers were failed to earn higher return because of lower yields of potato from farmers practice method [1,28] in good agreement with our findings. The study indicates that irrigation improves potato tuber yields and also that there are potato genotypic differences in water use. Consequently, rain-fed conditions resulted in a greater reduction in tuber yield than partially irrigated potatoes. Growers need to understand the growing stages and related daily water use of their heritage potatoes in order to improve yield and WUE.

Not just production costs but also yield and yield quality may be influenced by irrigation systems and strategies. Eventually the actual field experiments played a major role in the above farm economic assessment of water saving irrigation systems and strategies. When it comes to issues other than saving water, saving energy and yield improvements; different irrigation system offers even more benefits and options such as irrigation with waste water and fertigation. These options, however, are not addressed in this study.

5. CONCLUSIONS

Potato is relatively sensitive to soil water deficits. As for all growth and development phenomena, supply of water and minerals is a general pre-requisite for tuberization. Irrigation scheduling should be based on avoiding water deficit during the period of stolonization and tuber initiation [18]. Savings can also be attained by allowing higher soil water depletion toward the ripening period so that all available stored water in the root zone is used by the crop. This practice may also hasten maturity. Correct timing of irrigation may save 1 to 3 irrigation applications [18]. The results will be helpful in formulating management practices to enhance the tuber yield and to improve resources use efficiency in potato production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Yohannes DF, Ritsema CJ, Solomon H, Froebrich J, van Dam JC. Irrigation water management: Farmers' practices, perceptions and adaptations at Gumselassa irrigation scheme, North Ethiopia. Agricultural Water Management. 2017;191: 16–28.
2. Magistro J, Roberts M, Haggblade S, Kramer F, Polak P, Weight E, Yoder R. A model for pro-poor wealth creation through small-plot irrigation and market linkages. Irrigation and Drainage. 2007;56:321–334.
3. World Bank. Agriculture for Development: World Development Report 2008. The World Bank, Washington DC; 2007.
4. Bouman BAM. A conceptual framework for the improvement of crop water productivity at different spatial scales. Agricultural Systems. 2007;93:43–60.
5. FAOSTAT, FAO Statistical Database; 2013. Available:http://faostat3.fao.org/home/index.html#DOWNLOAD_ (Accessed 2013.08.23)
6. Burlingame B, Mouillé B, Charrondière R. Nutrients, bioactive non-nutrients and anti-nutrients in potatoes. Journal of Food Composition and Analysis. 2009;22:494–502.
7. van Loon CD. The effect of water stress on potato growth development, and yield. American Potato Journal. 1981;58:51–69.
8. Ferdous Z, Anwar M, Rahman MA, Yasmine F, Nain J. Fertilizer management for Maize-Mungbean-T. aman based cropping pattern. Journal of Agroforestry and Environment. 2011;5:129–132.
9. Anowar MM, Ferdous MZ, Islam M. Determination of nutrient management for potato-mungbean-T. aman based cropping pattern. Bangladesh Journal of Progressive Science & Technology. 2012;10(2):173-176.

10. Anwar M, Ferdous Z, Sarker MA, Hasan AK, Akhter MB, Zaman MAU, Haque Z, Ullah H. Employment generation, increasing productivity and improving food security through farming systems technologies in the Monga Regions of Bangladesh. Annual Research & Review in Biology. 2017;16(6):1-15.

    DOI: 10.9734/ARRB/2017/35645
11. Anowar M, Parveen A, Ferdous Z, Kafi AH, Kabir ME. Baseline survey for farmer livelihood improvement at farming system research and development, Lahirirhat, Rangpur. International Journal of Business, Management and Social Research. 2015;2:92–104.
12. Ahmed NU, Ferdous Z, Mahmud NU, Hossain A, Zaman MAU. Effect of split application of nitrogen fertilizer on the yield and quality of potato (*Solanum tuberosum*). International Journal of Natural and Social Sciences. 2017a;4(2): 60–66.
13. Datta A, Ullah H, Ferdous Z. Water management in rice. In: BS Chauhan, K Jabran, G Mahajan (Eds.), Rice Production Worldwide. Springer. 2017;255–277.

    Available:http://link.springer.com/chapter/10.1007/978-3-319-47516-5_11
14. Blackwell MSA, Brookes PC, de la Fuente-Martinez N, Gordon H, Murray PJ, Snars KE, Williams JK, Bol R, Haygarth PM. Phosphorus solubilization and potential transfer to surface waters from the soil microbial biomass following drying–rewetting and freezing–thawing. Advances in Agronomy. 2010;106:1–35.
15. Wang Y, Liu F, de Neergaard A, Jensen LS, Luxhøi J, Jensen CR. Alternate partial root-zone irrigation induced dry/wet cycles of soils stimulate N mineralization and improve N nutrition in tomatoes. Plant & Soil. 2010;337:167–177.
16. Suriyagoda LDB, Ryan MH, Renton M, Lambers H. Plant responses to limited moisture and phosphorus availability: A meta-analysis. Advances in Agronomy. 2014;124:143–200.
17. Bünemann EK, Keller B, Hoop D, Jud K, Boivin P, Frossard E. Increased availability of phosphorus after drying and rewetting of a grassland soil: processes and plant use. Plant & Soil. 2013;370:511–526.
18. Mulubrehan K, Gebretsadikan TG. Yield and water use efficiency of furrow irrigated potato underregulated deficit irrigation, Atsibi-Wemberta, North Ethiopia. Agricultural Water Management. 2016;170: 133–139.
19. Ahmed NU, Mahmud NU, Zaman MA, Ferdous Z, Halder SC. Effect of different salinity level on tomato (*Lycopersicon esculentum*) production under climate change condition in Bangladesh. Annual Research & Review in Biology. 2017b;13(3):1–9.

    DOI: 10.9734/ARRB/2017/33613
20. Datta A, Shrestha S, Ferdous Z, Win CC. Strategies for enhancing phosphorus efficiency in crop production systems. In: A. Rakshit, H.B. Singh, and A. Sen (Eds.), Nutrient Use Efficiency: from Basics to Advances. Springer. ISBN: 978-81-322-2169-2. 2015;59–71.

    Available:http://link.springer.com/chapter/10.1007/978-81-322-2169-2_5

    (Verified August 07, 2016)
21. Sun Y, Cui X, Liu F. Effect of irrigation regimes and phosphorus rates on water and phosphorus use efficiencies in potato. Scientia Horticulturae. 2015;190:64–69.
22. Ferdous Z, Datta A, Anal AK, Anwar M, Khan MR. Development of home garden model for year round production and consumption for improving resource-poor household food security in Bangladesh. NJAS - Wageningen Journal of Life Science. 2016;78:103–110.

    Available:http://doi.org/10.1016/j.njas.2016.05.006
23. Ferdous Z, Datta A, Anwar M. Effects of plastic mulch and indigenous micro-organism on yield and yield attributes of cauliflower and tomato in inland and coastal regions of Bangladesh. Journal of Crop Improvement. 2017;31:261–279.

    DOI: 10.1080/15427528.2017.1293578
24. Mahamood NU, Ferdous Z, Anwar M, Ali R, Sultana M. Yield maximization of maize through nutrient management. Progressive Agriculture. 2016;27(4):428–434.
25. Fandika IR, Kemp PD, Millner JP, Horne D, Roskruge N. Irrigation and nitrogen effects on tuber yield and water use efficiency of heritage and modern potato cultivars. Agricultural Water Management. 2016;170:148–157.
26. Rosen CJ, Kelling KA, Stark JC, Porter GA. Optimizing phosphorus fertilizer management in potato production.

American Journal of Potato Research. 2014;91:145–160.
27. Laboski CAM, Andraski TW. Potato response to phosphorus fertilizers: 2008 results. In: Proceedings. Wisconsin Annual Potato Meetings. 2009;22:139–154.
28. Rahman MM, Yasmine F, Rahman MA, Ferdous Z, Kar PS. Performance of poultry bio-slurry as a source of organic manure on potato production. Journal of Agroforestry and Environment. 2011;5:81–84.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/22411