Pertanika J. Trop. Agric. Sci. 38 (1): 83 - 92 (2015)

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Development of Fertilizer Recommendation for Aquatic Taro (*Colocasia esculenta*) in Grey Terrace Soil

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ABSTRACT

A field experiment was conducted to find out optimum doses of N, P, K and S for yield maximization of aquatic taro (*Colocasia esculenta*) during the summer seasons of 2008-2009 and 2010-2011 in Grey Terrace Soil (poorly drained, grey, and silty) of Gazipur. There were four levels of nitrogen (0, 75, 100 and 125 kg ha^{-1}), four levels of phosphorus (0, 30, 45 and 60 kg ha^{-1}), four levels of potassium (0, 80, 100 and 120 kg ha^{-1}) and four levels of sulphur (0, 10, 20 and 30 kg ha^{-1}). The experiment was laid out in a randomized complete block design with three replications. The yield attributes and yield of aquatic taro were significantly increased by the application of NPKS fertilizers. The highest stolon yields (25.60 and 28.16 t ha^{-1} for 2008-09 and 2010-11, respectively) were found in $N_{100}P_{45}K_{100}S_{20}$ kg ha^{-1} combination. From the regression analysis, it could be concluded that around 110-50-105-24 kg ha^{-1} N-P-K-S was the optimum dose for the production of aquatic taro in Grey Terrace Soil of Gazipur.

Keywords: Colocasia esculenta, fertilizers, optimum dose, yield

ARTICLE INFO

Article history:
Received: 12 December 2013
Accepted: 7 April 2014

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ISSN: 1511-3701

INTRODUCTION

Panikachu (*Colocasia esculenta* L.) is one of the most common aroids. It is grown in low lying and swampy areas of the Philippines (Pardales & Villancieva, 1984; Onwueme, 1999), Southern China (Matthews, 2000; Yongping *et al*., 2003), Bangladesh (Rana & Adhikary, 2005) and India (Sen *et al*., 1998; Saud & Baruah, 2000). Rhizome and stolon (trailing suckers) are edible, and though they are primary for stolon, the rhizomes which are not of good quality may be considered for some other uses. The stolon emerging continuously from the base of the developing sucker corms are highly acceptable as vegetable due to its non-acridity and taste (Sen *et al*., 19998). Panikachu (cv Latiraj) is famous for the production of good quality stolon. It is highly nutritious and palatable. Stolon contains 1.12 g iron, 38 mg calcium, 500 IU vitamin A, 38 mg vitamin C and 35 Kilocalorie food energy under 100 g edible portion (Bhuiyan *et al.,* 2008). It is also a promising crop for exporting to the foreign countries. In Bangladesh, stolon producing Panikachu occupies an area of about 6,886 ha, with a total production of 38,502 tonnes of stolon, and an average yield of 5.6 tonnes per hectare in 2009-10 (BBS, 2010). Generally, it is harvested throughout the kharif season when vegetables are deficit in the market. So, it can easily meet up the demand of vegetables at that time. It can grow easily with less care and input. Moreover, disease and insect infestations are less in case of Latiraj. Thus, there is a great opportunity to improve its production and quality through nutrient management.

Fertilizer management is one of the major determining factors to get the maximum yield of any crop. Nasreen and Islam (1989) stated that the major causes of low yield in crops may be either due to lack of high yielding varieties or poor fertility management. Judicious and proper use of manures and fertilizers are essential to get good yield (Sadhu, 1993). There is no fertilizer recommendation for Latiraj yet. So, the experiment was initiated to study the response of Latiraj to added nutrients and to find out the optimum doses of nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) so as to maximize the yield and develop a package of fertilizer for recommendation.

MATERIALS AND METHODS

Experimental Site and Soil Characteristics

The experiment was conducted at Tuber Crops Research Centre, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh during the summer seasons of 2008-09 and 2010-11. The experimental site is located at the centre of the Madhupur Tract at about 24^0 23´ north latitude and 90^0 08´ east longitude. The experimental plot was medium low land having silty clay soil. The soils are poorly drained, grey and silty and overlie heavy, grey, little-altered, deeply weathered Madhupur or Piedmont clay. The major part of the subsoil is an E-horizon (FAO, 1988; Brammer, 1996). The soil was slightly acidic (pH of 6.4) and low in exchangeable K (0.14 c mol kg^{-1}) and total N (0.10%). The soil boron (B) and zinc (Zn) contents were at par with critical level, while P and S were above the critical levels (Critical levels of P and S were 14 and 14 ppm, respectively and that of K was 78.2 ppm).

Treatment Details, Fertilizer and Manure Application

The treatment combinations were: T1=$N_0P_{45}K_{100}S_{20}$ kg ha^{-1}, T2=$N_{75}P_{45}K_{100}S_{20}$ kg ha^{-1}, T3=$N_{100}P_{45}K_{100}S_{20}$ kg ha^{-1}, T4=$N_{125}P_{45}K_{100}S_{20}$ kg ha^{-1}, T5=$N_{100}P_0K_{100}S_{20}$

kg ha^{-1}, T6=$N_{100}P_{30}K_{100}S_{20}$ kg ha^{-1}, T7=$N_{100}P_{60}K_{100}S_{20}$ kg ha^{-1}, T8=$N_{100}P_{45}K_{0}S_{20}$ kg ha^{-1}, T9=$N_{100}P_{45}K8_{0}S_{20}$ kg ha^{-1}, T10=$N_{100}P_{45}K_{120}S_{20}$ kg ha^{-1}, T11=$N_{100}P_{45}K_{100}S_{0}$ kg ha^{-1}, T12=$N_{100}P_{45}K_{100}S1_{0}$ kg ha^{-1}, T13=$N_{100}P_{45}K_{100}S3_{0}$ kg ha^{-1} and T14=Native nutrient (control).

The experiment was laid out in a randomized complete block design (RCBD) with three replications. Urea, triple superphosphate (TSP), muriate of potash (MoP) and gypsum were used as the sources of N, P, K and S, respectively. The entire quantities of phosphorus, potassium and sulphur were applied before planting and mixing into the soil. Nitrogen was to-dressed at 30, 50 and 70 DAP (days after planting).

Planting and Harvesting

Aquatic taro (*Colocasia esculenta*) variety of Latiraj was used as a test crop. The unit plot size was 3 m × 4.5 m. Seedlings of aquatic taro were planted with a spacing of 60 cm × 45 cm on 1st and 5th April of 2008 and 2010, respectively. The stolon was harvested at 60 DAP and harvesting continued 10 days interval throughout the growing season up to October.

Intercultural Operation

The field was intensively kept free from weeds for the first three months. Standing water of 8-10 cm was maintained in the field. Sometimes, the standing water was shaken and drained out. Dead leaves were removed regularly from the field. In some areas of the field, leaf blight disease was found to have occurred, and this was treated by spraying Ridomyl gold @ 2 gL^{-1} water for 3 times at 30-days interval.

Soil Sampling and Chemical Analysis

Soil samples were collected, dried and ground for chemical analysis. Bulk density was determined by using core sampler Method (Blake, 1965), soil pH by glass electrode pH meter (1:2.5) and organic carbon by wet oxidation method (Walkley & Black, 1935). Total N content of soil was determined by using the Kjeldahl method (Jackson, 1973), whereas available P, exchangeable K and available S contents by using 0.5M $NaHCO_3$ (pH 8.5), NH_4OAc and $CaCl_2$ extraction methods, respectively, as outlined by Page *et al*. (1982).

Data Collection

Yield attributes (plant height, number of leaves, number of stolon and stolon length) were recorded from 10 randomly selected plants. Stolon yield per plot was recorded and based on that, per hectare yield was calculated.

Statistical Analysis

The analysis of variance for yield attributes and yield was done following the ANOVA (analysis of variance) test and the mean values were compared by DMRT (Steel & Torre, 1960). One-way ANOVA table was used to perform this analysis. Computation and preparation of graphs were done using Microsoft EXCEL 2003 programme.

RESULTS AND DISCUSSION

Effects of Fertilizers on the Growth Parameters of Aquatic Taro

Plant height, number of leaves, number of stolon and stolon length were significantly influenced by the application of fertilizers. Plant height ranged from 60.6 to 79.9 cm and 63.1 to 87.9 cm in 2008-09 and 2010-11, respectively. The highest plant height (79.9 and 87.9 cm for 2008-09 and 2010-11, respectively) was found in T3 ($N_{100}P_{45}k_{100}S_{20}$ kg ha^{-1}), followed by T4 ($N_{125}P_{45}K_{100}S_{20}$ kg ha^{-1}). Treatments T3, T4, T7 and T10 showed statistically similar plant height. The lowest plant height (60.6 and 63.1 cm for 2008-09 and 2010-11, respectively) was in the control (Table 2). Mehla *et al*. (1997) reported that the plant height of *Colocasia esculenta* increased significantly after the applications of 150 kg N and 50 kg P per hectare at Haryana, India. The fertilizers had significant effect on the number of leaves. In particular, T3 showed the highest number of leaves (4.00 and 4.40 for 2008-09 and 2010-11, respectively), followed by T4 (3.87 and 4.09). The lowest number of leaves (3.00 and 3.30 in 2008-09 and 2010-11, respectively) was in the control. Mehla *et al*. (1997) observed the maximum number of leaves plant^{-1} of *Colocasia esculenta,* with 100 kg N ha^{-1} and 50 kg P ha^{-1}. Meanwhile, Verma *et al.* (1996) reported the maximum number of leaves plant^{-1} with 80 kg N ha^{-1} and 120 kg K ha^{-1}, and the results corroborated with the findings of the current work. The number of stolon plant^{-1} was also significantly variable among the different treatment combinations. The highest number of stolon plant^{-1} (29.7 and 32.7 in 2008-09 and 2010-11, respectively) was found in T3, and this was followed by T7 (28.0 and 30.8 for 2008-09 and 2010-11, respectively). The lowest number of stolon (17.4 and 19.2 for 2008-09 and 2010-11, respectively) was in the control (Table 2). It was found that the number of stolon increased with the increase in nitrogen levels. A similar result was also observed by Sen *et al*. (1998) in swamp taro. The fertilizers showed significant effects on stolon length. The maximum stolon length (100.7 and 110.8 cm in 2008-09 and 2010-11, respectively) was obtained in T3, and this was followed by T4 (95.8 and 99.0 cm for 2008-09 and 2010-11, respectively). The minimum stolon length (63.7 and 70.1 cm for 2008-09 and 2010-11, respectively) was in the control (Table 2). In 2008-09, T3, T4, T7, T10 and T11 showed statistically similar stolon lengths. Alam *et al*. (2010) reported that the highest stolon length was found in 125-36-125 kg ha^{-1} of N-P-K, which is in agreement with the finding of our study.

Effects of Fertilizer on the Stolon Yield

Stolon yield was significantly influenced by the fertilizers. In more specific, stolon yields ranged from 8.80 to 25.6 t ha^{-1} and 7.68 to 28.2 t ha^{-1} for 2008-09 and 2010-11, respectively. The highest stolon yield (25.6 and 28.2 t ha^{-1} in 2008-09 and 2010-11, respectively) was found in T3 ($N_{100}P_{45}K_{100}S_{20}$ kg ha^{-1}), which was significantly higher than the other treatments. Meanwhile, T4 ($N_{125}P_{45}K_{100}S_{20}$ kg ha^{-1}) showed the second highest yield (22.05 and 24.92 t ha^{-1} for 2008-09 and 2010-11, respectively), and

TABLE 1
Initial fertility status of soils of the experimental field

Soil properties	pH	OM %	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Mn	Zn
			meq/100g				$\mu g\ g^{-1}$						
2008-09	5.5	1.10	4.2	4.1	0.18	0.11	15	17	0.2	6	112	35	2.2
2010-11	5.6	1.08	4.1	4.2	0.19	0.12	18	18	0.2	7	115	36	2.4
Critical level	-	-	2.0	0.80	0.20	-	14	14	0.2	1	10	5	2.0

TABLE 2
Yield and yield attributes of aquatic taro (*Colocasia esculenta* L.) as influenced by different fertilizer levels

Treat.	Plant height (cm)		Number of leaves		Number of stolon		Stolon length (cm)		Stolon yield ($t\ ha^{-1}$)	
	2008-09	2010-2011	2008-09	2010-2011	2008-09	2010-2011	2008-09	2010-2011	2008-09	2010-2011
T_1	66.6 cd	72. 2 c	3.4 c	3.7 ab	22.8 ef	25.1 abc	73.5 fg	80.8 bc	13.4 fg	14.8 ef
T_2	70.1 bc	77.1 bc	3.6 bc	3.9 ab	26.6 bcd	29.3 ab	84.0 def	92.4 abc	21.6 cd	23.8 b
T_3	79.9 a	87.9 a	4.0 a	4.4 a	29.7 a	32.7 a	100.7 a	110.8 a	25.6 a	28.2 a
T_4	76.3 ab	83.9 ab	3.9 ab	4.1 ab	27.1 bc	27.8 ab	95.7 abc	99.0 ab	22.7 bc	24.9 b
T_5	69.2 bcd	73.4 c	3.5 bc	3.8 ab	21.5 f	23.7 bc	77.5 ef	85.2 abc	14.9 e	16.4 e
T_6	70.0 bc	77.0 bc	3.5 bc	3.8 ab	24.5 cde	26.9 ab	84.0 c-f	92.4 abc	19.7 d	21.7 c
T_7	71.8 abc	83.9 ab	3.7 abc	4.3 ab	27.9 ab	30.8 ab	92.0 a-d	101.2 ab	21.9 cd	24.1 b
T_8	66.7 bcd	79.0 bc	3.4 c	3.9 ab	24.1 def	23.5 bc	81.5 def	79.8 bc	12.6 g	13.9 f
T_9	70. 7 bc	77.7 bc	3.5 bc	3.9 ab	26.8 bc	29.5 ab	88.2 b-e	97.0 ab	21.7 cd	23.8 b
T_{10}	73.3 abc	80.6 abc	3.7 abc	4.1 ab	27.9 ab	30.7 ab	95.7 abc	105.2 ab	22.6 bc	24.8 b
T_{11}	69.1 bcd	73.0 bc	3.4c	4.1 ab	24.1 def	26.5 ab	72.6 fg	89.7 abc	12.4 g	13.6 f
T_{12}	69.5 bcd	76.0 c	3.5 c	3.8 ab	24.0 def	26.4 ab	78.3 def	86.1 abc	16.6 e	18.2 d
T_{13}	71.8 abc	76.1 bc	3.7 abc	4.0 ab	27.9 ab	29.7 ab	90.0 a-d	105.3 ab	21.8 cd	23.9 b
T_{14}	60.6 d	63.1 d	3.0 d	3.3 b	17.4 g	19.2 c	63.7 g	70.1 c	8.80 h	7.68 g
CV (%)	6.90	5.52	5.9	12.8	5.7	13.9	7.5	14.7	7.12	5.64

Figures in a column having common letters do not differ significantly at 5% level of LSD. Notes: T1=$N_0P_{45}K_{100}S_{20}$ kg ha^{-1}, T2=$N_{75}P_{45}K_{100}S_{20}$ kg ha^{-1}, T3=$N_{100}P_{45}K_{100}S_{20}$ kg ha^{-1}, T4=$N_{125}P_{45}K_{100}S_{20}$ kg ha^{-1}, T5=$N_{100}P_0K_{100}S_{20}$ kg ha^{-1}, T6=$N_{100}P_{30}K_{100}S_{20}$ kg ha^{-1}, T7=$N_{100}P_{60}K_{100}S_{20}$ kg ha^{-1}, T8=$N_{100}P_{45}K_0S_{20}$ kg ha^{-1}, T9=$N_{100}P_{45}K8_0S_{20}$ kg ha^{-1}, T10=$N_{100}P_{45}K_{120}S_{20}$ kg ha^{-1}, T11=$N_{100}P_{45}K_{100}S_0$ kg ha^{-1}, T12=$N_{100}P_{45}K_{100}S1_0$ kg ha^{-1}, T13=$N_{100}P_{45}K_{100}S3_0$ kg ha^{-1}, T14=Native nutrient.

TABLE 3
Response function of aquatic taro (*Colocasia esculenta* L.) to nitrogen, phosphorous, potassium and sulphur

Nutrient	Regression equation	Optimum dose (kg ha^{-1})	Economic dose (kg ha^{-1})	Maximum stolon yield (t ha^{-1}) for optimum dose	Production of stolon (t ha^{-1}) for 1 kg nutrient (use efficiency)	Beyond optimum dose the reduction of stolon yield (t ha^{-1}) for 1 kg nutrient
N 2008-09	$y = -0.0009x^2 + 0.1982x + 13.295$	110.1	109.4	24.21	0.10	0.9
N 2010-11	$y = -0.001x^2 + 0.2179x + 14.623$	108.95	108.30	26.49	0.24	0.1
P 2008-09	$y = -0.0033x^2 + 0.3349x + 14.545$	50.7	47.7	23.03	0.17	3.3
P 2010-11	$y = -0.0036x^2 + 0.3683x + 16.002$	51.15	50.28	25.42	0.51	3.6
K 2008-09	$y = -0.001x^2 + 0.2088x + 12.545$	104.4	103.6	23.44	0.10	1.0
K 2010-11	$y = -0.0011x^2 + 0.2297x + 13.797$	104.4	103.27	25.78	0.25	1.1
S 2008-09	$y = -0.0201x^2 + 0.9745x + 11.49$	24.4	24.3	23.40	0.49	20.0
S 2010-11	$y = -0.0223x^2 + 1.0757x + 12.638$	24.12	24.08	25.59	1.06	22.3

Considering the fact that 1 kg N, P, K, S and stolon is priced at 26, 125, 50, 34 and 20 Tk, respectively.

this was followed by T10 (22.56 and 24.82 t ha^{-1} in 2008-09 and 2010-11, respectively). The lowest stolon yield (8.80 and 7.86 t ha^{-1} for 2008-09 and 2010-11, respectively) was in the control (Table 2). Prajapati *et al*. (2003) reported that maximum yield attributes and yield were found with 120 kg N ha^{-1}. Since nitrogen is the constituent of chlorophyll and protein, its application might have increased the photosynthetic activities, increased length of stolon and rhizomes. Similarly, Alam *et al*. (2010) also reported that the highest stolon yield (24.5 t ha^{-1}) was recorded with 125 kg N and 125 kg K ha^{-1}, which is in agreement with the findings of our study. Mandal *et al*. (1982) also observed the highest cormel yield with $N_{120}K_{120}$ kg ha^{-1}.

Response Function

Positive but quadratic relationship was observed between the stolon yield of aquatic taro and added nutrients (N, P, K and S) in both the years (Fig.1 and Fig.2). From the regression equation, the optimum doses of nitrogen appeared as 110.1 and 108.95 kg ha^{-1} during 2008-09 and 2010-11, respectively. Similarly, the optimum doses of phosphorus were 50.7 and 51.15 kg ha^{-1} for 2008-09 and 2010-11, respectively. In

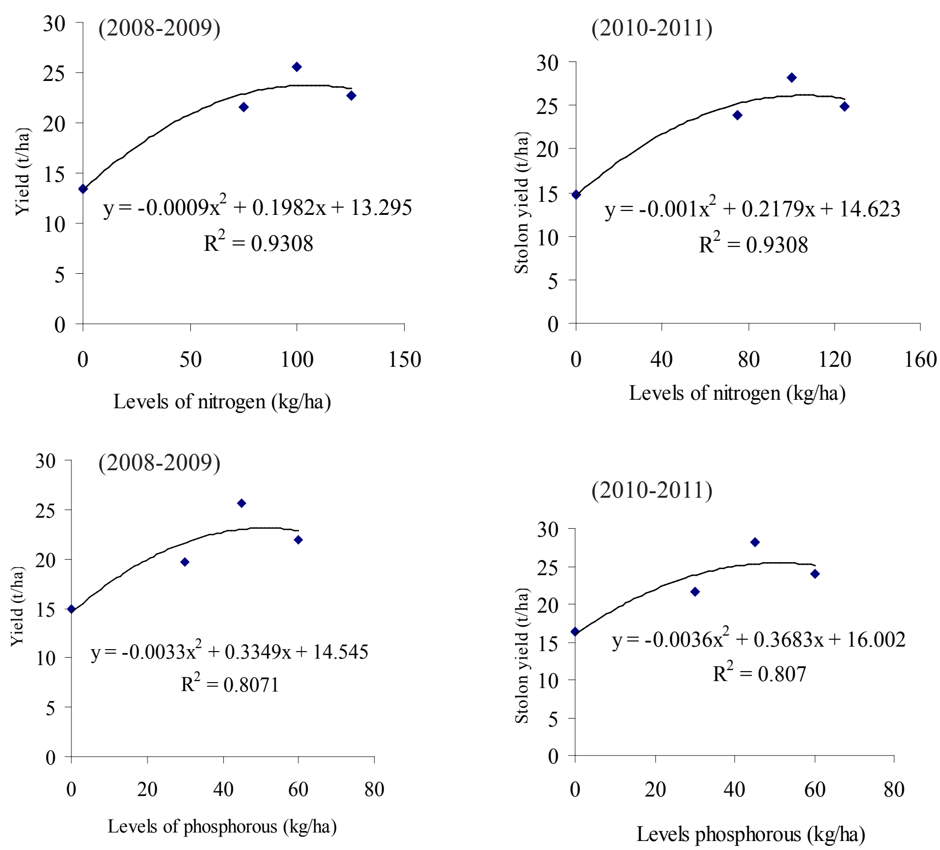

Fig.1: Responses of aquatic taro (*Colocasia esculenta* L.) to the added nitrogen and phosphorous

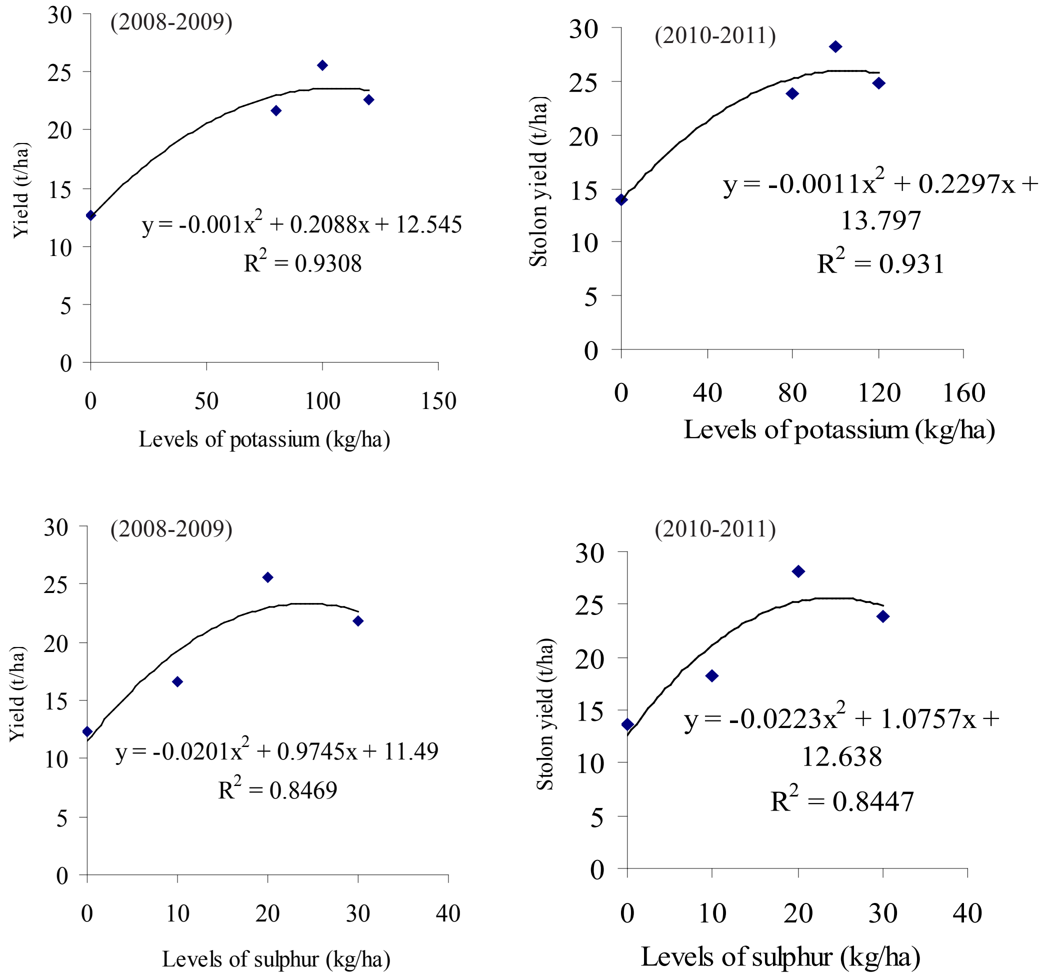

Fig.2: Responses of aquatic taro (*Colocasia esculenta* L.) to the added potassium and sulphur

the case of potassium, the optimum dose was 104.4 kg ha^{-1} in both the years. The optimum doses of sulphur were 24.4 and 24.22 kg ha^{-1} for 2008-09 and 2010-11, respectively (Table 3). Beyond the stated optimum dose, there is a possibility of losing certain amounts of yield if higher levels of nutrients were applied.

CONCLUSION

The different combinations of inorganic fertilizers showed significant effects on the yield parameters and yield of aquatic taro. The highest stolon yields (25.60 and 28.16 t ha^{-1} for 2008-09 and 2010-11, respectively) were found in the $N_{100}P_{45}K_{100}S_{20}$ kg ha^{-1} combination. The optimum doses of nitrogen, phosphorus, potassium and sulphur were 110, 50, 105 and 24 kg ha^{-1}, respectively.

ACKNOWLEDGEMENTS

The authors are thankful to the Bangladesh Agricultural Research Institute for financial support and to TCRC for facilitating the experiment. We also wish to express our gratitude to the unknown reviewers who have made valuable comments and suggestions to improve the manuscript.

REFERENCES

Alam, M. S., Reza, M. H., Islam, M. M., Bhuiyan, M. K. R., & Hossain, M. (2010). Effect of split application of NK fertilizers on the yield of panikachu (*Colocasia esculenta* L.)

Annual Report for 2109-10. Tuber Crops Research Centre, Bangladesh Agril. Res. Inst., Gazipur-1701, Bangladesh.

BBS (Bangladesh Bureau of Statistics). (2010). *Statistical Year Book of Bangladesh-2010*. Bangladesh Bureau of Statistics, Stat. Div. Minis. Planning, Govt. Peoples Repub. Bangladesh, Dhaka.

Blake, G. R. (1965). Bulk density. In C.A. Black (Ed.), *Methods of Soil Analysis, Part I* (pp. 374-390). Madison, Wisconsin, USA: American Society of Agronomy Inc.

Bhuiyan, M. K. R., Rahman, M. M., Alam, M. S., Islam, A. T. M. T., Hossain, M., & Begum S. N. (2008). *Production technology of newly released aroids variety* (In Bangla). Tuber Crops Research Centre, Bangladesh Agricul. Res. Inst., Gazipur: TCRC Publication.

Brammer, H. (1996). *The Geography of the Soils of Bangladesh*. Dhaka, Bangladesh: University Press Ltd.

FAO. (1988). *Land resources appraisal of Bangladesh for agricultural development*. Rome, Italy: FAO Publications.

Jackson, M. L. (1973). *Soil Chemical Analysis*. New Delhi, India: Prentice Hall of India Pvt. Ltd.

Mandal, R. C., Singh, K.D., & Maini, S. B. (1982). Effect of nitrogen and potash fertilization on tuber yield and quality of colocasia. *Vegetable Science*, *9*, 82-84.

Matthews, P.J. (2000). An introduction to the history of taro as food. In M. Nakatani & K. Komaki (Eds.), *Potential of root crops for food and industrial research* (pp. 484-497). Proceedings of the 12th Symposium of the International Society of Tropical Root Crops. Tsukuba, Japan: ISTRC Press.

Mehla, C.P., Ram, M., & Singh J. (1997). Effect of spacing and fertilizer levels on growth and yield of colocasia (*Colocasia esculenta* L.). *Agricultural Science Digest, 17*, 205-208.

Nasreen, S. & Islam, M. S. (1989). Response of Chilli to N P K and S fertilization. *Bangladesh Horticulture*, 17, 5-9.

Onwueme, I. (1999). *Taro cultivation in Asia and the Pacific*. Food and Agricultural Organization of the United Nations Regional Office for Asia and the Pacific, Bangkok.

Page, A.L., Miller, R.H., & Keeney, D.R. (1982). *Methods of Soil Analysis* (2nd Edn.). Madison, WI., USA: Amercen Society of Agronomy.

Pardales, J.R. & Villanueva, M.R. (1984). Cultural management for lowland taro under monoculture system in the Philippines. In S. Chandra (Ed.), *Edible Aroids*. UK: Clarendon Press.

Prajapati, M., Singh, P.K., Verma, R.B., & Singh, H.K. (2003). Yield and quality response of Colocasia (*Colocasia esculenta* L.) to FYM, nitrogen and potassium application. *Journal of Root Crops, 29*, 42-45.

Rana, P. & Adhikary, D. (2005). *Developing agricultural markets through business services*. Paper presented at the ADB-DFID MMW4P Workshop held during February 2005 at Manila, Philippines.

Sadhu, M. K. (1993). Root crops. In T. K. Bose, M.G. Som, & J. Kabir (Eds.), *Vegetable Crops* (pp. 470-578). Calcutta, India: Naya Prokash.

Saud, B.K. & Baruah, R.K.S.M. (2000). Pani-Kachu-special taro cultivation in Southern Assam. *Intensive Agriculture, 38*, 26-27.

Sen, H., Das, S., & Dwivedi, A.K. (1998). Stolon production of different organic and inorganic nitrogenous fertilizers. *Journal of Root Crops, 24*, 81-84.

Steel, R. C. B. & Torrie, J. H. (1960). *Principles and procedures of statistics* (pp. 377-398). New York, USA: McGraw Hall Book Publication.

Verma, R. B., Singh, P.K., & Singh, S.B. (1996). Effect of nitrogen and potassium levels on growth, yield and nutrient uptake of *Colocasia esculenta*. *Journal of Root Crops, 22,* 139-143.

Walkley, A.C. & Black, T.A. (1935). Estimation of soil organic carbon by chromic acid titration method. *Soil Science, 47*, 29-38.

Yongping, Y., Jianchu, X., & Eyzaguirre, P. (2003). Taro biodiversity management and conservation in Yunnan, China. In CIP-ESEAP (Ed.), *Conservation and Sustainable Use of Agricultural Biodiversity* (p.89-99). Bogor, Indonesia: CIP-UPWARD Press.