Indian J. Agric. Res., 52(5) 2018: 554-559
Print ISSN:0367-8245 / Online ISSN:0976-058X

AGRICULTURAL RESEARCH COMMUNICATION CENTRE
www.arccjournals.com/www.ijarjournal.com

Growth, yield and water use of drip irrigated cassava planted in the late rainy season of Northeastern Thailand

A. Polthanee* and M. Srisutham

Department of Plant Science and Agricultural Resources,
Faculty of Agriculture, Khon Kaen University, Thailand.
Received: 19-02-2018 Accepted: 09-08-2018 DOI: 10.18805/IJARe.A-339

ABSTRACT

Field experiment was carried out at Agronomy Experimental Farm, Faculty of Agriculture, Khon Kaen University in 2015-2016 to investigate the response of cassava to supplementary irrigation during the dry season month. The experiment was laid out in split plot design with four replications. The main plots comprised two cassava varieties (Huaybong 80 and Rayong 11). The sub l included four levels of drip irrigation [I-20, EV-40 mm (crop received 20 mm of water when daily cumulative pan evapolation value reached 40 mm during the dry season months)]; [I-20, EV-60 mm] ; [I-10, EV-40 mm] ; [I-10, EV-60 mm] and [I-10] (cassava under rainfed condition without additional irrigation)]. Results indicated that irrigation at (I-20, EV-40 mm) produced maximum the fresh (52 t ha^{-1}) and dry (22 t ha^{-1}) storage root yield. Huaybong 80 variety a gave significantly higher the storage root yield than that of Rayong 11 variety. The highest starch content also was obtained in the (I-20, EV-40 mm) treatment. There was no significant difference in the starch content between the two cassava varieties. Water were applied in treatment [I-20, EV-40 mm], [I-20, EV-60 mm], [I-10, EV-40 mm] and [I-10, EV-60 mm] was an average 299 mm, 194 mm, 150 mm and 97 mm, respectively during the growing season. Water use efficiency was the highest (35.3 kg ha^{-1} mm^{-1}) in the [I-20, EV-60 mm] treatment.

Key words: Cassava, Drip irrigation, Storage root yield, Water use efficiency.

INTRODUCTION

Northeastern Thailand has a semi-humid tropical climate which is characterized by wet (May-October) and dry (November-April) season (Goto *et al.* 2008). Cassava is a cash crop of small holding farmers beside sugarcane and maize. Its planting usually takes place in the early or end of the wet season. Nowadays, farmers prefer to plant cassava at the end of wet season. This is due to the fact that weed competition tends to be less severe in the dry season. Later, plant canopies are already well established during the early part of the rainy season. However, cassava planted at the end of rainy season will be exposed to prolong drought in the dry season, influencing various physiological processes resulting in depressed growth, development and economic yield (Bakayoko *et al.* 2009).

Drip irrigation has proved to be a successful in terms of water usage and increased yield as well as improved product quality (Mohamed Amanullah *et al.* 2014). Water saving was found under drip irrigation (Ramana Rao *et al.* 2017; Kahlon, 2017) as well as reduces cost of cultivation (Pawa *et al.* 2015). With drip irrigation, the soil is maintained continuously in a condition which is highly favorable for crop growth (Edoga and Edoga, 2006). In recent years, farmers in Northeast Thailand installed farm pond to collect water during the rainy season or tube wells were installed on the farm and shallow underground water pumped to supplementary irrigation in the dry season. Drip irrigation at various water regime for cassava planted at the end of rainy season has been tested in the previous experiment (Polthanee and Srisutham, 2017). Noticeably, in such experiment crop received 15 mm or 30 mm of water when the daily cumulative pan evaporation value reached 40 mm or 60 mm seem to access water supply. To save water and maximizing productivity under water scarcity, therefore, the objective of this research was to investigate the effects of various irrigation water regimes at low rates on growth, root yield and starch content of cassava planted in the end of rainy season.

MATERIALS AND METHODS

Location of field experiment: The study was conducted at the Agronomy Experimental Farm of the Khon Kaen University, Thailand (lat. 16° 28/ N, long. 102° 48/ E, 200 m AMSL). Northeast Thailand is characterized by a tropical climate, characterized by distinct wet and dry seasons. The soil texture of the experimental field is loamy sand with pH 5.96, organic matter 0.622%, available N 2.7 mg kg^{-1}, available P 34.67 mg kg^{-1} and exchangeable K 41.04mg kg^{-1}.

Experimental design and treatments: The experiments were laid out in a split plot design with four replications. Main plots consisted of two cassava varieties; Huaybong 80 and Rayong 11. Five different water regimes based on daily

*Corresponding author's e-mail: panan@kku.ac.th

cumulative pan evaporation value were applied to the sub-plots, (Table 1).

Lateral drip irrigation was laid out at 100 cm spacing between rows. Drippers were placed at 100 cm apart along the lateral line, meter were installed to determine the quantity of water used in each treatment.

Cultural practices: The experimental field was thoroughly ploughed, two times, by 3-disk tractor and 7-disk tractors, forming 40 cm high ridges. The rows and cassava plants was (1x1 m) apart. Each plot (4 m x 6 m) was separated by a 2 m wide space for demarcation between plots; totally forty plots, including the control treatment. Two hand weeding was undertaken at 1 month after planting (MAP). Stem cutting of 15 cm long were inserted vertically into the soil on the top of ridges. Granule fertilizer grade 15-7-18 [N, P_2O_5, K_2O] at rate of 156 kg ha^{-1} was applied to all treatments at 1 MAP post weeding. Crop were planted using residual soil moisture for germination and initial growth. Initial irrigation treatments were applied based on daily cumulative pan evaporation, as assigned for each sub-plot treatment. The experiment was conducted from 16 October 2015 to 6 October 2016.

Crop data: Five plants from each treatment were selected at random outside the harvesting area at 4, 8 and 12 MAP to determine the number of storage roots. After the number of storage root per plant was recorded, the plants were separated into leaf, stem and root to determine storage root fresh weight and dry weight per plant, leaf and stem fresh weight and dry weight per plant. The storage root yield was determined from the harvesting area of 4 x 8 meter and calculating to ton per hectare. Starch content (%) was recorded using the Riemarne balance method (Bainbridge *et al.* 1996). Harvest index (HI) was determined by calculating the storage root dry weight divided by total plant dry weight.

Water data: The experimental field located at a distance of 150 meter from the meteorology station. The values of pan evaporation, maximum and minimum air temperatures, relative humidity and rainfall are presented in Table 2.

Soil moisture content: The soil moisture content (% by weight) was determined by gravimetric measurement at 0.15 cm, 15-30 cm and 30-45 cm two week intervals of non-irrigated control plot in the dry season (Fig. 1) and in the wet season (Fig. 2). Soil moisture content was calculated using formula (Donahue *et al.* 1977) below:

$$\% \text{ Moisture} = \frac{(\text{wet soil weight}) - (\text{oven dry soil weight})}{\text{oven dry soil weight}} \times 100 \quad (1)$$

Data analysis: Data were analyzed statistically according to the analysis of variance (ANOVA) procedures using statistic version 8 (STAT8) software (Analytical Software,

Table 1: Irrigation treatments, water allotments, and designations.

Sub plot (1)	The crop received 20 mm of water when the daily cumulative pan evaporation value reached 40 mm	(I-20, EV-40 mm)
Sub plot (2)	The crop received 20 mm of water when the daily cumulative pan evaporation value reached 60 mm	(I-20, EV-60 mm)
Sub plot (3)	The crop received 10 mm of water when the daily cumulative pan evaporation value reached 40 mm	(I-10, EV-40 mm)
Sub plot (4)	The crop received 10 mm of water when the daily cumulative pan evaporation value reached 60 mm	(I-10, EV-60 mm)
Sub plot (5)	The no-irrigation (control) group	(I-0)

Note: All treatments received similar amounts (1192 mm) of natural rainfall during the rainy season.

Table 2: Weather data of the experimental site during the 2015/2016 cropping season.

Month	Rainfall (mm)	Evaporation (mm day^{-1})	Relative humidity (%)	Temperature (°C) Maximum	Temperature (°C) Minimum
Oct. 2015	46.9	3.83	89	31.7	23.2
Nov. 2015	5.7	5.19	86	33.7	22.7
Dec. 2015	0.0	4.69	87	32.6	20.3
Jan. 2016	16.5	4.16	87	32.0	19.5
Feb. 2016	0.0	5.96	78	32.2	16.3
Mar. 2016	1.8	6.89	77	36.9	21.8
Apr. 2016	87.9	7.97	76	40.3	26.9
May.2016	40.1	5.78	87	36.1	25.4
Jun. 2016	186.2	5.07	89	35.4	25.5
Jul. 2016	207.4	4.02	91	22.5	24.5
Aug. 2016	204.7	4.84	90	32.9	24.5
Sept. 2016	287.6	3.38	93	32.3	24.3
Oct. 2016	115.8	3.33	92	32.2	23.9
Total	1191.6	65.11	1122	430.8	298.8
Mean	91.7	5.01	86.3	33.1	22.9

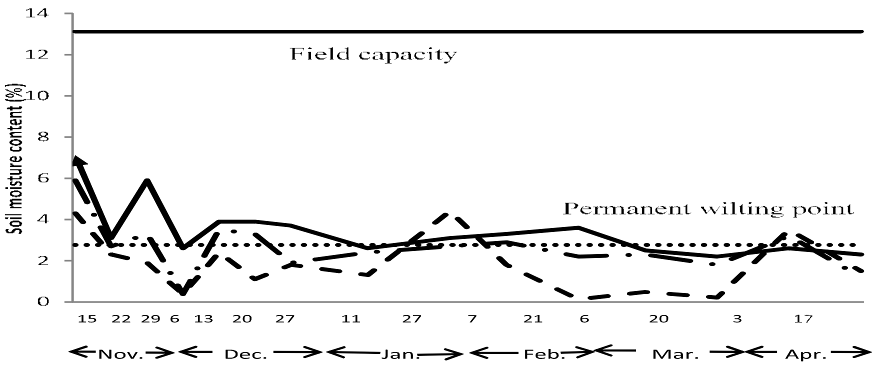

Fig 1: Soil moisture content (% by weight) of non-irrigated control plot at 0-15 cm (- - -), 15-30 cm (-.-.) and 30-45 cm (⟵) depth below soil surface in dry season.

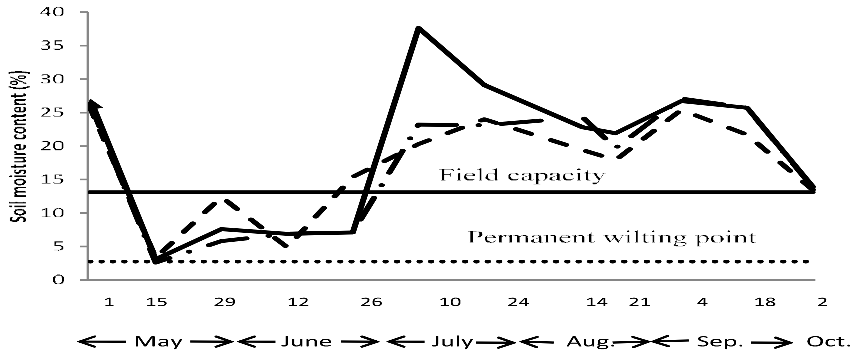

Fig 2: Soil moisture content (% by weight) of non-irrigated control plot at 0-15 cm (- - -), 15-30 cm (-.-.) and 30-45 cm (⟵) depth below soil surface in wet season.

USA) to test the significant (*P<0.05*) for single factors and interactions for split plot design.

RESULTS AND DISCUSSION

Leaf dry weight: The leaf dry weight was significantly affected by irrigation treatments across both varieties at 4 (*P≤0.05*), 8 (*P≤0.01*) and 12 (*P≤0.05*) MAP (Table 3). The highest leaf dry weight was observed in the (I-20, EV-40 mm) treatment at 4, 8 and 12 MAP. Variety Rayong 11 produced a significantly higher (*P≤0.05*) leaf dry weight than those of Huaybong 80 at 12 MAP across all irrigation regimes (Table 3). The non-irrigated (control) treatment significantly decreased the leaf dry weight across both varieties as compared to all irrigation treatments (Table 3).

Stem dry weight: The irrigation treatments significantly increased the stem dry weight in comparison with the non-irrigated (control) across both varieties at 4 (*P≤0.05*), 8 (*P≤0.01*) and 12 (*P≤0.01*) MAP (Table 3). The maximum stem dry weight was obtained in the (I-20, EV-40 mm) treatment at 4, 8 and 12 MAP. For variety, Rayong 11 gave a significantly higher stem dry weight than those of Huaybong 80 at 12 MAP across all irrigation regimes (Table 3).

Number of storage root: All irrigation treatments significantly increased the number of storage root per plant over the non-irrigated control treatment across two varieties at 4, 8 and 12 (*P≤0.05*) MAP (Table 4). The highest number of storage root per plant was observed in the (I-10, EV-60 mm) treatment at 4 MAP. While, the maximum number of storage root per plant was obtained in the (I-20, EV-40 mm) treatment at 8 and 12 MAP. In the present experiment, number of storage root was not significantly affected by cassava variety across all irrigation treatments at 4, 8 and 12 MAP (Table 4).

Storage root fresh weight: All irrigation treatments significantly increased the storage root fresh weight per plant across two varieties at 4, 8 and 12 (*P≤0.05*) MAP (Table 4). The maximum storage root fresh weight per plant was observed in the (I-20, EV-40 mm) treatment at 4, 8 and 12 MAP. Across all irrigation treatments, Huaybong 80 produced a significantly higher storage root fresh weight per plant (*P≤0.05*) than Rayong 11 at 12 MAP.

Storage root yield: All irrigation treatments significantly increased the storage root yield both fresh and dry weight (*P≤0.01*) in non-irrigated (control) treatment across two varieties (Table 5). The highest fresh storage root yield (52 t ha^{-1}) and dry storage root yield (22 t ha^{-1}) were obtained in the (I-20, EV-40 mm) treatment. In the present study, Huaybong 80 produced a significantly higher (*P≤0.05*) fresh and dry storage root yield than those of Rayong 11 across all irrigation treatments (Table 5).

Table 3: Leaf and stem dry weight (g plant-1) of cassava under drip irrigation water regimes at 4, 8 and 12 months after planting (MAP).

Treatment	Leaf dry weight			Stem dry weight		
	4	8 MAP	12	4	8 MAP	12
Variety (V)						
Huaybong 80	40.5	101.3	120.4 b	62.3	195.5	630.5 b
Rayong 11	42.1	112.3	154.3 a	66.4	204.4	807.4 a
Irrigation regime (I)						
I-20,40 mm	58.2 a	114.3 a	157.9 a	83.6 a	241.9 a	809.8 a
I-20,60 mm	51.5 a	112.3 a	155.3 a	79.4 a	215.9 ab	751.7 a
I-10,40 mm	45.3 bc	112.5 a	138.1 a	71.8 a	212.1 ab	732.2 a
I-10,60 mm	34.2 c	110.6 a	135.6 a	53.7 b	182.7 bc	833.9 a
I-0	17.4 d	84.2 b	99.8 b	27.4 c	147.4 c	416.9 b
F-test						
V	ns	ns	*	ns	ns	*
I	*	*	*	*	**	**
V x I	ns	ns	ns	ns	ns	ns

Means followed by the same letter at the same column were not significantly different by LSD at P<0.05; * significant at P<0.05, ** significant at P<0.01, ns = not significant.

Table 4: Number of storage root per plant and storage root fresh weight of cassava under drip irrigation water regimes at 4, 8 and 12 months after planting (MAP).

Treatment	Number of storage root			Storage root fresh weight (g $plant^{-1}$)		
	4	8 MAP	12	4	8 MAP	12
Variety (V)						
Huaybong 80	5.3	7.1	10.9	441.7	1550.2	4978.0 a
Rayong 11	5.5	6.8	10.1	306.8	1530.0	3878.5 b
Irrigation regime (I)						
I-20,40 mm	6.5 a	8.7 a	11.8 a	520.8 a	2256.3 a	5042.5 a
I-20,60 mm	6.4 a	8.2 ab	11.2 a	511.7 a	2271.9 a	5215.0 a
I-10,40 mm	5.7 a	6.9 b	10.7 a	486.6 a	1556.3 b	4105.0 ab
I-10,60 mm	7.1 a	7.8 ab	10.6 a	255.8 b	965.6 ab	4567.5 ab
I-0	1.8 b	3.1 c	8.2 b	94.2 c	650.5 c	3211.3 c
F-test						
V	ns	ns	ns	ns	ns	*
I	*	*	*	*	*	*
V x I	ns	ns	ns	ns	ns	ns

Means followed by the same letter at the same column were not significantly different by LSD at P<0.05; * significant at P<0.05, ns = not significant.

Table 5: Storage root yield, harvest index and starch content of cassava under drip water irrigation regimes at harvest.

Treatment	Storage root yield (t ha^{-1})		Harvest index	Starch content
	Fresh weight	Dry weight	(HI)	(%)
Variety (V)				
Huaybong 80	49.69 a	21.75 a	0.74 a	30.98
Rayong 11	39.50 b	18.06 b	0.65 b	30.97
Irrigation regime (I)				
I-20,40 mm	52.12 a	22.44 a	0.70 ab	31.81 a
I-20,60 mm	48.88 a	21.94 a	0.72 a	31.74 a
I-10,40 mm	45.69 a	19.56 a	0.69 ab	32.34 a
I-10,60 mm	43.56 a	19.13 a	0.71 a	30.55 ab
I-0	32.62 b	16.19 b	0.67 b	28.43 b
F-test				
V	*	*	*	ns
I	**	**	*	*
V x I	ns	ns	ns	ns

Means followed by the same letter at the same column were not significantly different by LSD at P<0.05; * significant at P<0.05, ** significant at P<0.01, ns = not significant.

Harvest index: The harvest index was significantly affected (*P≤0.05*) by irrigation treatments across both varieties (Table 5). The highest harvest index value was observed in the (I-20, EV-60 mm) treatment. In the present experiment, Huaybong 80 illustrated a significantly greater harvest index value across all irrigation treatments than those of Rayong 11 (Table 5).

Starch content: The irrigation treatments of (I-20, EV-40 mm), (I-20, EV-60 mm) and (I-10, EV-40 mm) significantly increased (*P≤0.05*) the starch content of storage root at harvest across both varieties as compared to non-irrigated control (Table 5). The highest starch content was obtained in the (I-10, EV-40 mm) treatment. In the present study, starch content was not significantly affected by cassava variety across all irrigation treatment (Table 5).

Relationship between water regimes and storage root yield: In the present experiment, Huaybong 80 and Rayong 11 illustrated the coefficient of determination 0.918 and 0.967, respectively (Fig 3). This indicates a positive corresponding between the storage root yield and their root yield increases as the water application increases.

Water use efficiency: Water consumption in the (I-20, EV-40 mm), (I-20, EV-60 mm), (I-10, EV-40 mm), (I-10, EV-60 mm) and control treatment (I-0) was 1491, 1386, 1342, 1289 and 1192 mm, respectively (Table 6). The water use efficiency (WUE) values ranged from 33.8-35.3 kg ha^{-1} mm^{-1}. Drip irrigation in the (I-10, EV-60 mm), (I-10, EV-40 mm), (I-20, EV-40 mm) and (I-20, EV-60 mm) increased the WUE by 23.4, 24.5, 27.7 and 28.8%, respectively as compared to (I-0) control treatment (Table 6).

Yield attributes and yield: The yield and yield attributes (leaf and stem dry matter) were significantly increased by all irrigation treatments as compared to non-irrigated control (cassava under rainfed condition without additional irrigation). This was associated with higher storage root number and storage root fresh weight per plant as compared to the non-irrigated (rainfed) control. Sarkar *et al.* (2017) also stated that plants under higher water supply recorded higher dry matter accumulation, leaf area index and leaf area duration, whereas the lowest values of such traits were more pronounced at rainfed treatment. In the present study, irrigation treatments increased the storage root yield by 34-60% as compared to rainfed crops, depending on the amount of water application. Sunitha *et al.* (2013) reported that storage root yield increased in irrigated crops by 77-93% as compared to rainfed crops, depending on irrigation level (100% of pan evaporation, PE; 80% PE and 60% PE). In another irrigation experiment, the storage root yield increased by 24-43% above non-irrigated (rainfed) treatment, depend upon irrigation methods (surface drip irrigation, sub-surface drip at 10 cm and sub-surface drip at 40 cm) (Sinworn and Duangpatra, 2014). Our results determined that the Huaybong 80 variety produced significantly higher storage root fresh weight per plant, and subsequently higher storage root yield than that of Rayong 11 variety. Although, the Huaybong 80 variety gave the leaf dry weight lower than Rayong 11 variety in the present study, but it can produced higher the storage root yield than the Rayong 11 variety. This was due to Huaybong 80 provided harvest index value greater than Rayong 11 (Table 5). This indicates that Huaybong 80 variety performed better ability to translocate

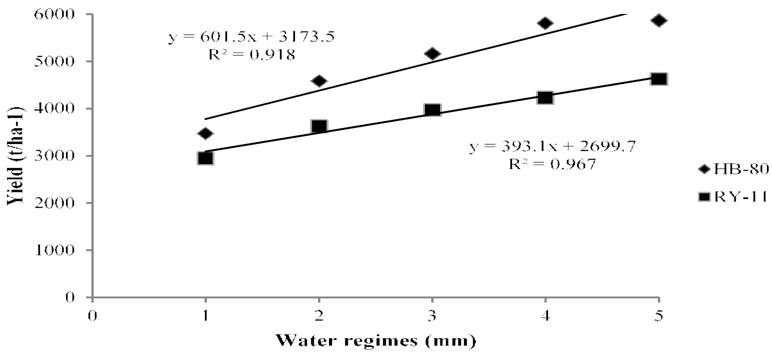

Fig 3: Linear regression between water regimes and storage root yield of two cassava varieties (1=1192 mm, 2=1289 mm, 3=1342 mm, 4=1386 mm, and 5=1491 mm).

Table 6: Total water use and water use efficiency under drip irrigation water regimes.

Parameters	$I_{-20,EV\text{-}40\ mm}$	$I_{-20,EV\text{-}60\ mm}$	$I_{-10,EV\text{-}40\ mm}$	$I_{-10,EV\text{-}60\ mm}$	I_0
Irrigation water applied (mm)	299	194	150	97	0
Effective rainfall (mm)	1192	1192	1192	1192	1192
Total water used (mm) (TWU)	1491	1386	1342	1289	1192
Total applied water to TWU (%)	20.05	13.99	11.18	7.53	0.00
Storage root yield (kg ha^{-1})	52150	48863	45675	43550	32631
Water use efficiency (kg ha^{-1} mm^{-1})	35.0	35.5	34.1	33.8	27.4
Water use efficiency increased (%)	27.7	28.8	24.5	23.4	-

the photosynthate from leaves to the storage root than those of Rayong 11 variety.

Starch content: The irrigation treatments of (I-20, EV-40 mm), (I-20, EV-60 mm) and (I-10, EV-40 mm) significantly increased the starch content as compared to non-irrigated control treatment. This result was similar to the findings of Hular-Bograd *et al.* (2011). However, this result is in contrast to the reported by Samutthong *et al.* (2010); Sinworn and Duangpatra (2014) and Polthanee *et al.* (2014).

Water use efficiency: The crop consumed 1491, 1386, 1342, 1289 and 1192 mm of water for the whole period in the sub-plot (I-20, EV-40 mm), (I-20, EV-60 mm), (I-10, EV-40 mm), (I-10, EV-60 mm) and (I-0) control, respectively. The data indicated a gradual reduction in water use efficiency with decreasing quantity of irrigation. Percentage increase in WUE was ranged from 27-35% as compared to rainfed crop, which observed maximum in the (I-20, EV-60 mm) and minimum in the (I-0) control. This clearly reveals that supplementary irrigation during dry season months increase cassava storage root yield, though the crop is reported to be drought tolerant. Increase in water use efficiency in cassava under irrigations ranges from 77-93%, depending on irrigation water levels as compared to rainfed crops (Sunitha *et al.* 2013). Further reported a WUE increasing by 133-213% in cassava under irrigation as compared to rainfed crops, depending on irrigation regimes (Sunitha *et al.* 2016).

CONCLUSION

The possibility of increasing the cassava production per unit land area can be achieved by supplemental drip irrigation. The above finding clearly revealed that cassava responds well to supplementary irrigation during the dry season months. Drip irrigation at 20 mm of water when the daily cumulative pan evaporation value reached 40 mm resulted in two fold increase in the storage root yield of cassava as compared to rainfed crops.

REFERENCES

Bakayoko, S., A. Tschannen, C. Nindjin, D. Dao, O. Girardin and Assa, A. (2009). Impact of water stress on fresh tuber yield and dry matter content of cassava (*Manihot esculenta* Crantz). *African J. of Agric. Res*., **4:** 21-27.

Bainbridge, Z. K., Tomlins, K., Wellings, K. and Westby, A. (1996). Methods for assessing quality characteristics of non-grain starch staples (Part 2. Field Methods.). Natural Resources Institute, Chatham, UK.

Donahue, R. L., Miller, R. W. and Shickluna, J.C. (1985). Soils: An introduction to soils and plant growth. Prentice-Hall, Inc., Englewood Cliffs, New Jersey 07632, U.S.A.

Edoga, R. N. and Edoga, M.O. (2006). Design of drip irrigation set for small vegetable gardens. *Notulae Bottanicae Horti Agrobotanici*, **34:** 1842-4309.

Goto, S., T. Kuwagata, P. Konghakote, A. Polthanee, Y. Ishigooka, H. Toritani and Hasegawa, T. (2008). Characteristics of water balance in a rainfed paddy field in Northeast Thailand. *Paddy and Water Environ*., **6:** 153-157.

Hular-Bograd, J., E. Sarobol, C. Rojanaridpiched and Sriroth, K. (2011). Effect of supplemental irrigation on reducing cyanide content of cassava variety Kasetsart 50. *Nat. Sci*., **45:** 985-994.

Kahlon, M.S. (2017). Effect of planting methods and irrigation levels on water productivity of onion (*Alleium cepa* L.). *Indian J. Agric. Res*., **51**(5): 510-513.

Mohamed Amanullah, M., S. Jusop, C.T. Boon Sung, P.E.M. Wahab and Panhwar, Q.A. (2014). Effects of drip irrigation frequency, fertilizer sources and their interaction on the dry matter and yield components of sweet corn. *Aust. J. of Crop Sci*. ISSN: 1835-2707.

Pawar, N., D.K. Bishnoi, M. Singh and Dhillon, A. (2015). Comparative economic analysis of drip irrigation vis-à-vis flood irrigation system on productivity of Bt. Cotton in Haryana. *Agric. Sci. Digest*., **35**(4): 300-303.

Polthanee, A., C. Janthajam and Promkhambut, A. (2014). Growth, yield, and starch content of cassava following rainfed lowland rice in Northeast Thailand. *International J. of Agric. Res*., **9**(6): 319-324.

Polthanee, A. and Srisutham, M. (2017). Supplementary irrigation for cassava planted in the late rainy season of Northeastern Thailand. *Asian Journal of Crop Science*. ISSN 1994-7879, DOI: 10.3923/ajcs.2017. 1-9.

Ramana Rao, K.V., S. Gangwar, A. Bajpai, R. Keshri, L. Chourasia and Soni, K. (2017). Performance of pea under different irrigation systems. *Legume Research,* **40**(3): 559-561.

Samutthong, N., E. Sorobol, V. Vichukit and Thongpae, S. (2010). Effects of amount and rate of watering on cassava growth and yield potential. Proceedings of the 45th Kasetsart University Annual Conference, Bangkok, Thailand, pp: 75-82. (in Thai).

Sarkar, S., A. Sarkar and Zaman, A. (2017). Effect of irrigation and phosphorus levels on broad bean (*Vicia faba* L.) for improving growth, yield and water extraction pattern. *Legume Research*., **40**(2): 257-263.

Sinworn, S. and Duangpatra, P. (2014). Effects of drip irrigation systems and chemical fertilizer on growth and yield of cassava in the dry season. *SDU Res. J*., **7**(2): 1-21. (in Thai).

Sunitha, S., G. James and Sreekumar, J. (2013). Productivity of cassava (*Manihot esculenta*) as affected by drip fertigation in the Humid Tropics. *J. of Root Crops*., **39**(2): 100-104.