Tuberisation pattern of tannia (*Xanthosoma sagittifolium* (L.) Schott) in response to crop management practices in the South-Central Laterites of Kerala, India

ABSTRACT

The study was conducted to outline the rooting and tuberisation pattern of tannia (*Xanthosoma sagittifolium* (L.) Schott) as influenced by different crop management practices. As an underutilised crop, it was uncertain as to the management techniques which would increase tuberisation and productivity levels of tannia. Hence the study was to promote tuberisation in tannia with a focus on the underground portions of the plant. The variation in rooting pattern was studied in terms of root number, root weight and root volume and the tuberisation pattern consists of cormels number per plant, corm weight per plant, cormel weight per plant and rate of tuber bulking. The study was conducted in farmers field at Ezhukone during the period from Feb 2021- Dec 2021. The experiment comprised three treatments in completely randomised design with six replications. The treatments were t_1 - Kerala Agricultural University Package of Practices Recommendations (KAU POP), t_2 - farmers' practice and t_3 - absolute control. The results revealed that, the root number (43.29), root weight (32.74 g plant^{-1}) and the root volume (38.22 g plant^{-1}) were significantly the highest in t_1 (KAU POP) at harvest followed by farmers' practice and absolute control. When considering the percentage increase in root production, KAU POP recorded 19.22 per cent, 8.79 percent, 11.04 per cent and 15.66 per cent, the highest number of roots respectively at 4 MAP, 6 MAP, 8 MAP and harvest than farmers' practice. The number of cormels per plant (12.16), corm weight per plant (563.16 g), cormel weight per plant (439.16 g) at harvest and the rate of tuber bulking (1.27 kg ha^{-1} d^{-1}) at 4 to 5 MAP were found to be the highest with t_1 followed by t_2 and t_3.

Keywords: Farmer's practice; package of practices, rate of tuber bulking; rooting pattern; tuberisation pattern.

INTRODUCTION

Cocoyams (*Xanthosoma* spp.) are the most extensive root and tuber crops cultivated almost everywhere throughout the tropics and in over 65 countries of the world [24]. Different types of crop production practices are followed for growing tannia in Kerala. They are grown in lands with even low innate soil fertility. The yield under the tannia has been fluctuating between 6 to 10 tonnes per hectare since the past. But now, it has reached 20 to 50 tonnes per hectare with disease free healthy planting materials and better cultural practices. Consequently, cocoyams could feed the growing global population [24, 23, 9].

It's an important food crop, which is consumed in many parts of the world. It is particularly essential for small holder farmers since it plays a significant role in the lives of many people as a food security crop and has socio-cultural ramifications [26, 22, 19]. Despite high productivity level, nutritional quality and better storability compared to other tuber crops; tannia has been relegated in agricultural policies and research on root and tuber crops and it remains an under exploited food resource [18, 6, 3].

The South-Central Laterites is a major tuber growing region of Kerala, cultivating tubers *viz*., cassava, yams, and aroids. It belongs to mid-land laterite terrain of strong acidic soil with plinthite. The districts of Thiruvananthapuram, Kollam, Pathanamthitta, Alappuzha, Kottayam and Ernakulam are covered by the 161 mid-land panchayats [2]. Several homesteads of South-Central Laterites have widespread cultivation of tannia, not only due to the crop adaptation, but also due to the stable market price of the crop. However, the farm-to-farm yield variability has been observed to be high, which could be attributed to the wide variation in the combination(s) of management practices adopted by the farmers.

Conventionally, tannia are fertilized with Farmyard Manure (FYM) and ash only. However, studies have revealed the positive influence of both organic manure and chemical fertilizers in tannia. The ICAR- CTCRI developed an Integrated Nutrient Management (INM) strategy consisting of FYM @ 25 t ha^{-1} + 80:50:150 kg NPK ha^{-1} [5] which resulted in higher yield. However, the tuberisation pattern of the crop in response to contrasting management practices has not been probed into in detail. In this backdrop, the present study was undertaken with the objective of elucidating the tuberisation pattern of tannia as a function of its response to the management practices.

1. MATERIAL AND METHODS

The study on tuberisation pattern of tannia as influenced by different crop production practices were conducted in South Central Laterites during 2021-2022 (February to December 2021). The field was located at Ezhukone in Kollam district which is situated at 9.02° N latitude and 76.7° E longtitude and at an altitude of 57 m above mean sea level. The objective of the study was to analyse the rooting pattern and tuberisation pattern of tannia grown under South Central Laterites.

The experiment was a pot study with three treatments and 6 replications laid out in completely randomized design (CRD). The treatments consisted of t_1 - KAU POP (Kerala Agricultural University Package of Practices), t_2 - farmers' practice and t_3 - absolute control.

Plastic sacks of 50 kg capacity were used for planting the corm pieces. The sacks were arranged in 90 x 90 cm from centre to centre. Potting mixture was prepared by mixing soil, sand, and farmyard manure (FYM) in the ratio 1: 1: 1. Potting mixture was filled uniformly in plastic sacks and the cormels (100 g each) were planted. The P^H of potting mixture was 5.45 and the oganic carbon content was 1.05 per cent in medium range. A local variety procured from the farmer's field was used for the study.   In treatment $t_{1,}$ dolomite (1 t ha^{-1}) was used as soil amendment at 15 days before sowing and (FYM 25 t ha^{-1}) was applied prior to sowing. Nutrients, viz., nitrogen (N), phosphorus (P) and potassium (K) were applied at 80: 50: 150 kg NPK ha,$^{-1}$. While FYM and P were applied as basal, N and K were applied in three split doses (2 MAP, 4 MAP and 6 MAP). In the case of N, 25 per cent was applied as chemical and 75 per cent as green manure (cowpea). Further, at 20 days after planting, *Azotobacter chroococcum* was applied at 10 g $plant^{-1}$ followed by the application of neem cake (375 kg ha^{-1}) after one month [11]. Green leaf mulching was also done at 15 t $ha.^{-1}$ In the case of farmers' practice (t_2) the inputs used for nutrient management were quantified. It comprised NPK dose of 25: 25: 50 kg ha^{-1}. Lime (350 kg $CaCO_3$ ha^{-1}) was used as soil amendment before the field preparation and ash (2 t ha^{-1}) was applied along with the fertilizers. The observations related to rooting pattern were recorded by adopting destructive sampling at 4^{th} MAP, 6^{th} MAP, 8^{th} MAP and at harvest. The crop was harvested when the upper part started yellowing and dried which was around nine months after planting.

3. RESULTS AND DISCUSSION

3.1 Rooting Pattern

The rooting pattern was observed at 4^{th}, 6^{th} and 8^{th} month after planting (MAP), and at harvest.

3.1.1 Root Number

The results revealed that the different crop production practices had significant effect on the root number per plant at all stages of crop growth (Table 1). In general, up to 6 MAP the number of roots showed an increasing trend in all the treatments. Among the three treatments, KAU POP (t_1) recorded the highest root number at 4 MAP (62.70), 6 MAP (86.67), 8 MAP (63.67) and at harvest (43.28). As expected, the absolute control recorded the lowest root number at harvest (13.86). When considering the percentage increase in root number, KAU POP recorded 19.22 per cent, 8.79 per cent, 11.04 per cent and 15.66 per cent more roots than the farmers' practice at 4 MAP, 6 MAP, 8 MAP and harvest respectively. From 6 MAP to 8 MAP and 6 MAP to harvest the percentage reduction in number of roots per plant was found lesser (25.54 % and 50.06 % respectively) in KAU POP (t_1) than farmers 'practice (t_2) (28.03 % and 53.03 % respectively).

Root growth could be normally impeded by harsh effects of acidic soil present in the South-Central Laterites. The application of lime is effective for recovering acid soils but not as fast as dolomite application since the mobility of lime is limited and further, the carbonates of Ca or Mg present in dolomite has been reported to neutralize the soil faster than lime. This might be the reason for the better root production observed on t_1 (KAU POP). The effect of dolomite over lime was previously reported by [25, 21, 4].

In addition, growth promoting effects of *Azotobacter chroococcum* by way of production of phytohormones and promotion of enzymatic activities as reported by [13] might have also resulted in improved root production of tannia with KAU POP.

3.1.2 Root Weight

Root weight per plant was observed to vary significantly among the three different crop production practices, (Table 1). The root weight per plant was observed to increase from 4 MAP to 6 MAP, later it decreased towards 8 MAP and harvest in all the treatments. KAU POP recorded the highest root weight per plant (48.03 g, 86.67 g, 46.03 g and 32.74 g) at all stages of observation followed by farmers' practice and absolute control. It was interesting to note that the percentage reduction in root weight from 6 to 8 MAP and 8 MAP to harvest was also the highest (70.11 %, 60.15 %) in t_3 (absolute control). Between t_1 (KAU POP) and t_2 (farmers' practice), the percentage reduction in root weight per plant during the period from 6 MAP to 8 MAP was more for t_2 (59.94 %) and from 8 MAP to harvest it was higher for t_1 (28.87 %). During the period from 6 MAP to harvest, KAU POP (t_1) recorded the least reduction in root weight per plant (62.22 %) followed by t_2 (70.27 %) and t_3 (88.09 %).

Studies have shown that the grand growth period of tannia occurred between 8-20 weeks [20]. In the present study, the root number and root weight showed an increasing trend up to 6 MAP and declined towards harvest. The highest root weight recorded with KAU POP (t_1) at all stages of observations could reflect the effect of balanced nutrition supported with higher doses of organic matter and adequate amelioration of the soil acidity. Similar results have been reported earlier in taro, from the lateritic soils of Kerala [14]. Further, the proper timing of application of soil amendments, nutrients and biofertilizer could also have contributed to the better root weight.

3.1.3 Root Volume

The data presented in Table 1 showed a significant difference in root volume of tannia under the influence of different crop production practices. KAU POP (t_1) Significantly recorded the highest root volume at all stages of crop growth. At harvest, the root volume recorded with KAU POP (t_1) was 41 per cent and 97.47 per cent greater than farmers' practice and absolute control respectively.

Apart from the beneficial effects of balanced nutrition, the enhancement observed in root volume with KAU POP (t_1) could also be attributed to the favourable effect of mulching. Mulching has been reported to improve the physical properties of soil, increase the soil nutrient content, and enhance the microbial activity of the soil resulting better availability of nutrients. Thus, the rooting volume might have increased to make use of the accessible nutrients. So, the higher root volume of tannia in t_1 might be due to the effect of the green mulching involved in it as observed previously in taro [17].

3.2 Tuberisation Pattern

Tuberisation pattern of tannia was recorded at 4^{th}, 6^{th} and 8^{th} month after planting (MAP), and at harvest.

3.2.1 Number of Cormels per Plant

Results on the effect of crop production practices on the number of cormels per plant in tannia are presented in Table 2. The treatment t_1 (KAU POP) recorded the highest cormel number per plant at all stages of observation (2.94 at 4 MAP, 5.79 at 6 MAP, 10.27 at 8 MAP, 12.16 at harvest). It was followed by farmers' practice. The variation in cormel count per plant between KAU POP and farmers' practice were to the tune of 56.38 per cent at 4 MAP, 61.73 per cent at 6 MAP, 34.42 per cent at 8 MAP and 46.15 per cent at harvest.

Table 1. Effect of crop production practices on root number, root weight and root volume per plant in tannia

Treatments	Root number				Root weight (g $plant^{-1}$)				Root volume (cm^3 $plant^{-1}$)			
	4 MAP	6 MAP	8 MAP	Harvest	4 MAP	6 MAP	8 MAP	Harvest	4 MAP	6 MAP	8 MAP	Harvest
t_1 - KAU POP	62.70	86.67	63.67	43.29	48.03	86.67	46.03	32.74	72.56	98.10	68.99	38.22
t_2 - Farmers' practice	52.59	79.67	57.33	37.43	30.72	79.67	31.92	23.68	66.00	86.61	56.69	27.10
t_3 - Absute control	23.36	45.00	22.24	13.87	12.62	45.00	13.45	5.37	38.10	52.26	38.44	19.35
SEm (±)	0.61	1.06	0.91	0.63	0.37	1.06	0.87	0.61	1.11	2.24	1.27	1.22
CD (0.05)	1.83	3.188	2.729	1.909	1.122	3.188	2.609	1.851	3.355	6.747	3.818	3.669

KAU POP - Kerala Agricultural University Package of Practices

MAP - Months After Planting

Split application of fertilizers in KAU POP (t_1) might have enhanced the production of tubers and reduced the loss of N [1]. Application of N, both as organic and inorganic would have more efficiently addressed the crop requirement. The time of application of N and K was significant in production of cormels [15]. Both, limited and excessive N could lead to decreased tuber size [18].

Integrated nutrient management is the pre-eminent combination for sustainable tuber yield as reported by [7]. The increased cormel production in KAU POP might also due to the additive effect of soil amelioration. These findings corroborate with those reported by [10].

3.2.2 Corm weight per plant

The data on the Table 2 represent the effect of crop production practices on corm weight per plant in tannia. There was noted a significant variation in corm weight per plant with the treatments. The highest corm weight per plant at 4 MAP, 6 MAP, 8 MAP and at harvest (397.83 g, 426.66 g, 478.27 g, 563.16 g respectively) was observed in KAU POP followed by farmers' practice. While comparing, the corm weight per plant at harvest in KAU POP was 53.73 per cent greater than farmers' practice and 217.27 per cent greater than absolute control.

The mean weight of cormel and corm were positively and significantly correlated with yield [16]. Bio fertilizer inoculations of *Azotobacter c.* in the field integrated with organic matter and reduced chemical fertilizer are reported to improve plant root growth and yield described by [8]. Application of organic matter addition and bio fertilizer in t_1 improves the weight of tuber in turn improves the yield.

3.2.3 Cormel weight per plant

Scrutiny of data on table 2 revealed that, cormel weight per plant also significantly varied among the three crop production practices. At 4 MAP, 6 MAP, 8 MAP and harvest, the KAU POP recorded the highest cormel weight (151.66 g, 217.41 g, 323.98 g and 439.16 g respectively). It was followed by farmers' practice and absolute control. The cormel weight per plant recorded in KAU POP was 63.16 per cent greater than farmers' practice and 182.42 per cent greater than absolute control.

It was reported by [13] formerly that the rapid availability of nutrients from chemical fertilizers could result in higher cormel weight during the earlier stages of crop growth. In the present study, chemical fertilizers supplemented with neem cake along with biofertilizer could also have resulted in the rapid and constant release of nutrients which might have in turn helped in the gain in weight and yield of tannia.

Table 2. Effect of crop production practices on number of cormels, corm weight and cormel weight per plant in tannia

Treatments	Number of cormels				corm weight (g plant^{-1})				Cormel weight (g plant^{-1})			
	4 MAP	6 MAP	8 MAP	Harvest	4 MAP	6 MAP	8 MAP	Harvest	4 MAP	6 MAP	8 MAP	Harvest
t_1 - KAU POP	2.94	5.79	10.27	12.16	397.83	426.66	478.27	563.16	151.66	217.41	323.98	439.16
t_2 - Farmers' practice	1.88	3.58	7.64	8.32	266.16	314.66	350.44	366.33	121.79	159.83	224.79	269.16
t_3 - Absolute control	0.74	2.05	4.15	5.24	68.48	111.36	157.79	177.50	70.16	110.83	142.16	155.50
SEm (±)	0.25	0.23	0.17	0.14	10.63	9.016	10.17	13.47	12.68	11.64	8.70	10.58
CD (0.05)	0.754	0.72	0.524	0.449	32.05	27.178	30.676	40.613	38.225	35.099	26.25	31.896

KAU POP - Kerala Agricultural University Package of Practices

MAP - Months After Planting

3.2.4 Rate of tuber bulking

The results on the rate of tuber bulking in tannia as influenced by crop production practices are depicted in Fig. 1. It is clear that, irrespective of the practice adopted, the rate of tuber bulking was higher at 4 MAP to 5 MAP. At 4 MAP to 5 MAP, the highest cormel bulking rate (1.27 kg ha^{-1} d-^{1}) was observed in KAU POP followed by farmers' practice (1.07 kg ha^{-1} d-^{1}) and absolute control (0.69 kg ha^{-1} d-^{1}). At 4 to 5 MAP, The tuber bulking rate under absolute control was 1.84 and 1.55 times lower than that under KAU POP and farmers' practice, respectively. From 5 to 6 MAP onwards the rate was decreased, where KAU POP (t_1) produced (0.84 kg ha^{-1} d-^{1}) followed by t_2 (0.68 kg ha^{-1} d-^{1}) and t_3 (0.29 kg ha^{-1} d-^{1}). At 6 to 7 MAP, KAU POP recorded 0.68 kg ha^{-1} d-^{1} rate of tuber bulking, and the farmers' practice and absolute control recorded (0.42 and 0.29 kg ha^{-1} d-^{1} respectively). At harvest, the least rate was observed.

It was reported by [12] that the highest cormel bulking rate of taro was noticed at 3 MAP to 4 MAP which denoted the period of active tuber development and hence the peak value was obtained here. After that a decreasing trend of bulking rate was observed towards harvest in all the treatments. Correspondingly in this experiment, the rate of tuber bulking was higher at 4-5 MAP, later the decrease was noted in all the treatments. The FYM application had significant effect on the rate of tuber bulking, but the effect was slow as it releases the nutrients slowly into the soil [13]. The crop production practice (KAU POP) which used FYM was reported the higher bulking rate among all treatments.

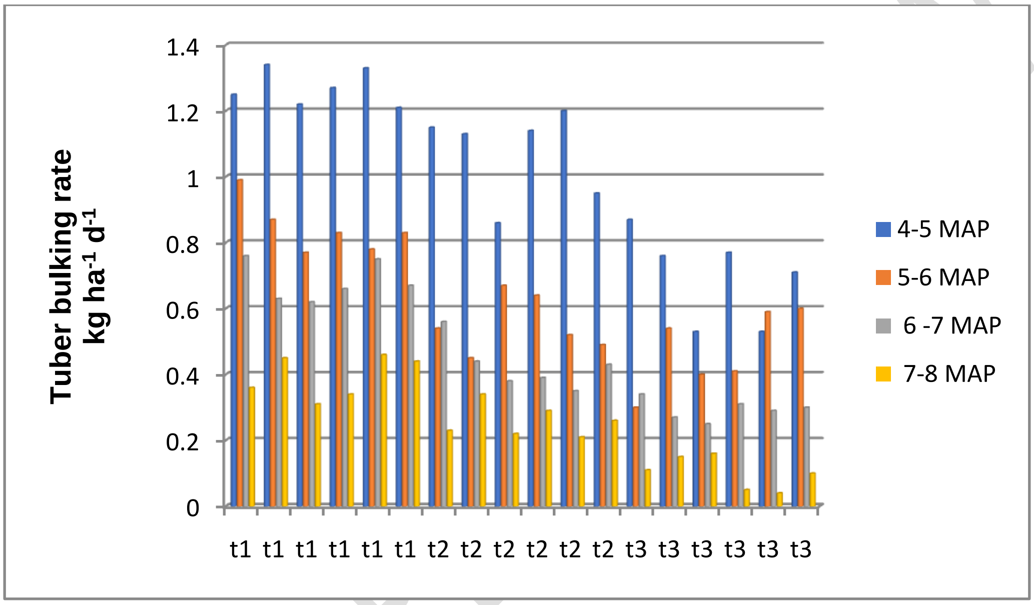

Fig. 1 Effect of different crop production practices on tuber bulking rate (kg $ha^{-1}d^{-1}$) of tannia

4. CONCLUSION

The multiple crop production practices tested in the present study affected the rooting and tuberisation pattern of tannia. Integrating both organic and inorganic fertilizers along with the recommended dose of fertilizers enhanced the rooting and tuberistion of tannia. Application of the nutrients at the rate of 80: 50: 150, N P K kg ha^{-1} in split doses was recorded as the best in acquiring root and tuber growth. The use of soil amendments and soil conditioners is crucial in acidic soil. However, the selection of the type of amendment / conditioner was more important as evidenced by the effectiveness of dolomite over lime in promoting better tuberisation in tannia. Application of green manures, bio fertilizers, and green mulches enhanced the cormel yield of tannia. Thus, the present study demonstrated that, good crop production techniques were crucial for the cultivation of tannia.

REFERENCES

1) 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. 2017; *4*(2): 60-66.
2) Anju PS, Susan J, Ray SB. Weighed average method in evolving the nutrient status of soils under cropping systems involving tuber crops in AEU 3 and AEU 9 of Kerala. Journal of Root crops 2019; 45(2): 33-41.
3) Boakye AA, Wireko-Manu, FD, Oduro, I, Ellis WO, Gudjónsdóttir, M. and Chronakis, IS. Utilizing cocoyam (*Xanthosoma sagittifolium*) for food and nutrition security: A review. Food Science and Nutrition, 2018; *6*(4): 703-713.
4) Castro GSA, Crusciol CAC. Effects of surface application of dolomitic limestone and calcium – magnesium silicate on soyabean and maize in rotation with green manure in a tropical region. Bragantia. 2015; 74: 311-321.
5) CTCRI [Central Tuber Crop Research Institute]. 2011. Annual report 2010-2011. ICAR - Central Tuber Crop Research Institute, Thiruvananthapuram, Kerala, India, 179p.
6) Falade KO, Okafor CA. Physicochemical properties of five cocoyam (*Colocasia esculenta* and *Xanthosoma sagittifolium*) starches. Food Hydrocolloids.2013; *30*(1): 173-181.
7) Ferdous Z, Anwar M, Rahman MA, Yasmine F and Nain J. Fertilizer management for potato mungbean - T. aman based cropping pattern. Journal of Agronomy and Environment.2011; 5: 129-132.
8) Hindersah R, Kamaluddin NN, Samanta S, Banerjee S, Sarkar S. Role and perspective of *Azotobacter* in crops production. SAINS TANAH – Journal of Soil science and Agroclimatology. 2020; 17(2): 170-179.
9) Inyang E. Cocoyam a major national carbohydrate staple for the future. Address presented at the 1st national workshop on cocoyam, 1987; 15.
10) Jayapal A, 2017, Tillage and nutrition for productivity enhancement in tannia (*Xanthosoma sagittifolium* (L.) schott) Doctoral dissertation, Department of Agronomy, College of Agriculture, Vellayani.
11) KAU [Kerala Agricultural University]. 2016. *Package of Practices Recommendations: Crops* (15th Ed.). Kerala Agricultural University, Thrissur, 393p.
12) Kumar MCR. 1986. Agronomic investigation on taro (*Colocasia esculenta* L.) var.Thamarakkannan. ph.D. thesis, Kerala Agricultural University, Thrissur, 240p.
13) Limisha N, Rajasree G, Isaac, SR. Growth characters and yield of taro [*Colocasia esculenta* (L.) Schott] as influenced by organic nutrient management. Journal of the Indian Society of Coastal Agricultural Research. 2022; *40*(2).
14) Mohankumar CR, Sadanandan N, Saraswathy P. Effect of levels of NPK and time of application of N and K on the yield of taro (*Colocasia esculenta* (L.) Schott). Journal of Root Crops. 1990 a; *16*(1): 33-38.
15) Mohankumar CR, Sadanandan N. Growth, and dry matter accumulation in colocasia. (*Colocasia esculenta* L. Schott) as influenced by NPK nutrition. Journal of Root Crops. 1989; 15 (2): 103-108.

16) Mohankumar CR, Saraswathy P, Sadanandan N. Correlation and path coefficient analysis on yield and yield components in colocasia. Journal of Root Crops. 1990 b; 6: 140-141.
17) Mohankumar CR. Agronomic investigations on colocasia (*Colocasia esculenta* L.) variety Thamarakannan. PhD. Thesis Kerala Agricultural University, Thrissur, 1986; 240p.
18) Ojala J, Stark J, Kleinkopf GE. Influence of irrigation and nitrogen management on potato yield and quality. American Potato Journal.1990; 67: 29–43.
19) Onyeka, J. Status of cocoyam (*Colocasia esculenta* and *Xanthosoma* spp) in West and Central Africa: production, household importance and the threat from leaf Blight. CGIAR Research Program on Roots, Tubers, and Bananas (RTB). 2014; pp.1-39.
20) Ramawat KG, Merillon JM (2014). Bulbous Plants: Biotechnology. CRC press, Taylor and Francis group, USA.
21) Sivan P. 1982. Growth and development of taro under dryland conditions in Fiji In: *Proceedings of fifth International Symposium on Tropical Root and Tuber Crops*, 17-21 September 1979, Los Banos, Philippines. Philippine Council for Agriculture and Resources Research, Philippines, pp. 637-646.
22) Soratto, RP, Crusciol CAC. Nutrition and grain yield of black oat as affected by surface application of lime and phosphogypsum at the establishment of no-tillage system. Revista Brasileira de Ciência do Solo, 2008; *32*: 715-725.
23) Towle MA (1961). Ethnobotany of Pre-Columbian Peru. Towle, M. A. (1961). The Ethnobotany of pre-Columbian Peru. Viking Fund Publicationin Anthropology N 30, Wenner Green Foundation for Anthropolog ical Research. Inc. New York. USA. 180p.
24) Ubalua AO, Ewa F, Okeagu, OD. Potentials and challenges of sustainable taro (*Colocasia esculenta*) production in Nigeria. Journal of Applied Biology and Biotechnology, 2016; 4 (01): 053-059.
25) Ubalua AO. Cocoyam (taro and tannia): staples with untapped enormous potentials – a Review. Plant Knowledge Journal, 2016; 5(1): 27-35.
26) Vacheron J, Desbrosses G, Bouffaud M, Touraine B, Moenne-Loccoz Y, Muller D, Legendre L, Wisniewski-Dye F, Prigent-Combaret C. Plant growth promoting rhizobacterian nand root system functioning. *Front. Plant Sci*. 2013; 4: 356-375.
27) Wada E, Asfaw Z, Feyissa T, Tesfaye K. Farmers perception of agromorphological traits and uses of cocoyam (*Xanthosoma sagittifolium* (L.) Schott) grown in Ethiopia. African Journal of Agricultural Research. 2017; *12*(35): 2681-2691.