



RESEARCH BRIEF PGIA

2018 TO 2023

POSTGRADUATE OF AGRICULTURE, UNIVERSITY OF PERADENIYA, PERADENIYA



2018-PhD

01. OPTIMIZATION OF SOME SELECTED AGRONOMIC PRACTICES AND USE OF IMAGE ANALYSIS TECHNIQUES TO IMPROVE YIELD AND QUALITY OF STRAWBERRY

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Abstract

The cultivated strawberry, *Fragaria x ananassa*, is a member of Rosaceae family. By the local people, the strawberry is referred to as “Green Gold” due to its higher economic gains. Therefore, it is worth to study regarding this precious crop by developing useful findings which can be used to increase the production end to uplift the income of local growers of strawberries. Experiments were conducted at Agriculture Research Station (ARS) Rahangala in the up country intermediate zone with the objective of developing an agronomic package for strawberry cultivation. The specific objectives of this study to reduce the usage of synthetic nitrogen and potassium fertilizers using compost and Tithonia (*Tithonia diversifolia* (Hemsley) A. Gray), study the effect of organic and inorganic fertilizers, effect of nitrogen on nursery plants, effect of mulching and to study relationship of red, green and blue colour (RGB) reflection of berry with its total soluble solid content (TSS) and study relationship between RGB reflection of strawberry leaves and its TSS. Strawberry cv. “Chandler” runner tips were established in 6 inches black polythene bags filled with coir dust and sand at equal proportions. Nursery plants were fed with N, P, K (20:20:20) (0.5 g/L/week) and nitrogen (0, 0.2 & 0.4 g of urea/plant/week) at different stages of growth. Elevating the nitrogen (0.19 g N/plant/week) during flower bud initiation of nursery plants produced the highest yield by increasing the number of inflorescences, flowers and yield. When increased the nitrogen (0.19 g N/plant/week) after flower buds differentiation, increase the numbers of runners. Therefore, the nitrogen management during, before and after the flower bud differentiation is highly important to get the maximum yield of strawberries. The effect of Tithonia green manure and compost were investigated with urea and MOP. Experiment was laid in RCBD with 3 replicates. Plot size was 3 x 2 m. Planting space was 30 x 40 cm. Strawberry yield did not reduced significantly with lowering urea and MOP by 25%, 50%, 75% ,100 % while incorporating Tithonia 2, 4, 6, 8 t/ha or compost 2, 3, 4, 5 t/ha respectively. Therefore, inorganic N, K fertilizers could be reduced by adding Tithonia at the rate of 2 t/ha or by adding compost at the rate of 1 t/ha starting from 2 t/ha for each 25 % reduction of synthetic N and K fertilizers. The effect of colour polythene on the yield and quality of strawberry were studied. Silver over black polythene mulch, white, green, blue and black polythene mulches were applied over the beds 21 days after planting strawberry plants. The effect of punctured, white polythene mulches was also studied. The white polythene mulches of single row of 10 cm apart punctures, double row of 10 x 10 cm punctures and un-mulched control were used. The strawberry could be planted on silver over black polythene, white polythene, green polythene, blue polythene or single or double row punctured white polythene mulch under up country intermediate zone conditions of Sri Lanka for higher yield and better quality of fruits without accumulation of free water on polythene surface. Photographs of fully red (FRC), three-quarter (TQC) and half (HC) coloured strawberry fruits and recently mature (RMTLs), mature (MTLs) and disease infected (DITLs) trifoliate strawberry leaves were taken. Red, green, blue colour intensities of images were analyzed. TSS of FRC, TQC and HC strawberry fruits were found significantly different. The highest TSS was seen in FRC (7.7⁰ Brix) and the lowest was seen in HC (5.3⁰ Brix). The RGB intensity and $[(G+B-R)/(R+G+B)]^2$ ratio were reduced with TSS of fruits. RGB reflection were increased when elevating brix values. Strawberry fruit could be harvested at the stage of three quarter coloured or fully red coloured in order to

obtained higher brix value. MTLs with lower brix value or higher $R/(R+G+B)$ value or lower $G/(R+G+B)$, G/R , $[(R+B-G)/(R+G+B)]^2$ values could be considered in removal practices of leaves. Strawberry yield can be increased by elevating nitrogen level (0.19 g N/plant/week) during 1-2 ½ months period of strawberry nursery plants. In addition, the application synthetic nitrogen and potassium can be reduced by adding Tithonia or compost to strawberry cultivation. The strawberry can be grown successfully with high yield on silver over black polythene, white polythene, green polythene, blue polythene except black polythene. Strawberries should be harvested at the stage more than ¾ red colour developed on berries for fresh consumption purpose.

2019-MPhil

02. PINEAPPLE (*ANANAS COMOSUS* VAR. *COMOSUS*) IMPROVEMENT BY HYBRIDIZATION

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Abstract

Mauritius and Kew are the major pineapple varieties grown in Sri Lanka. Considering the importance, Department of Agriculture, Sri Lanka initiated pineapple hybridization program in 1995 to develop improved varieties using Kew and Mauritius as parents. This program identified four promising hybrid progenies (H1, H2, H3 and H4) and among them two hybrids H3 (Kew ♀ x Mauritius ♂) and H4 (Kew ♀ x Mauritius ♂) observed to be better in terms of fruit shape, broad eyes, dark yellow flesh color and spiny tip leaves but fruit quality was not at acceptable level. To improve the fruit quality characteristics of developed hybrids (H3 and H4) a backcross program was initiated at the Regional Agriculture Research and Development Centre, Makandura, from January 2014 to August 2016. Concomitantly another study was initiated to ascertain the probable genotypic composition of Kew and Mauritius for leaf spininess. In the present study, H3 (Kew ♀ x Mauritius ♂) and H4 (Kew ♀ x Mauritius ♂) hybrids were backcrossed with Mauritius to improve the fruit quality as Mauritius considered having acceptable fruit quality characters. Plant and fruit characters and fruit quality parameters of 14 offspring obtained from H3♀ x Mauritius ♂ and 21 offspring derived from H4♀ x Mauritius ♂ backcrosses were evaluated. Result revealed that 3 offspring (number 3, 6, 13) derived from H3♀ x Mauritius ♂ backcross having greater sweetness index values than that of both parents but produced smaller fruits not suitable for table fruit and for canning. Seven offspring (number 1, 5, 8, 12, 13, 15, 17) derived from H4♀ x Mauritius ♂ backcross showed higher sweetness index values along with other fruit quality characters compared to both of parents. Among these offspring, only the offspring 13, 15 and 17 showed greater fruit quality characters than its parents and also had desirable plant and fruit characters suitable for both fresh and canning. These elite offspring also can be used as breeding material for future pineapple fruit quality improvement programs. The second experiment was conducted to determine the probable genotypic constitution of Kew and Mauritius for leaf spininess trait. F1 progeny obtained from Kew♀ x Mauritius ♂ cross evaluated for spiny character. Early seedling stage (5 months) evaluation showed 51.5 % offspring having common spiny character and 48.5 % plants having spiny tip character recording 1:1 ratio. Therefore, the probable genotypic constitution for Kew should be **ppSs** and for Mauritius **ppss**. P and S are the genes which control the spiny leaf trait of pineapple.

Key words: backcross, hybridization, Kew, Mauritius, offspring, sweetness index

03. INVESTIGATION OF GOAT MILK PRODUCTION WITH SUPPLEMENTAL THAMPALA (*AMARANTHUS HYPOCHONDRIACUS* L.) FEEDING

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Abstract

A study was carried out to compare the forage nutritional value and yield of five different amaranth cultivars namely, *Amaranthus hybridus*, *Amaranthus caudatus*, *Amaranthus hypochondriacus*, *Amaranthus cruentus*, *Amaranthus dubius* together with guinea 'A' grass (*Panicum maximum*), cowpea (*Vigna unguiculata*) and maize (*Zea mays*), at three different harvesting times, namely early bloom (50 dap) (days after planting), mid bloom (80 dap) and late bloom (110 dap) stages of the *Amaranthus* crop. A randomized complete block design (RCBD) with three replicates was used to compare eight plant species. Plants were harvested, yields were measured and sub samples were taken for proximate analysis. All amaranth species contained high crude protein (14.23-25.73%) and ash content (11.43-21.53%) compared to other forages studied. Forage dry matter yield of different species of amaranth ranged from 1570-5100 kg/ha. In addition, a feeding trial was carried out to evaluate the effect of incorporating 10% or 15% non- heat treated (NHT) or 10% or 15% heat treated (HT) amaranth (*Amaranthus hypochondriacus*) seed powder on milk yield, milk composition, milk fatty acid profile, milk cholesterol content, dry matter intake, body weight gain and blood serum parameters namely, total Cholesterol (TC), high density lipoprotein (HDLC) Cholesterol, low density lipoprotein (LDLC) Cholesterol and triacylglycerol (TAG) of Saanen lactating goats (*Capra hircus*), for a period of 3 months. A randomized complete block design with four replicates was used to compare five treatment groups. Control (basal diet) consisted of natural grass together with rice (*Oryza sativa*) bran and milling by products of black gram (*Vigna mungo*), whereas amaranth seed powder in different ratios as mentioned above was added to four experimental rations. All diets were formulated to meet NRC standards for Saanen dairy goats. Milk samples were collected for a period of 3 months and were analyzed for protein, fat, lactose and solid nonfat (SNF). Milk fat extracted from the samples were analyzed for fatty acid profile and cholesterol content. Dry matter intakes and body weights were recorded and blood samples were taken for a period of 03 months and concentration of TC, HDLC, LDLC and triacylglycerol were determined. Addition of amaranth seed powder into different treatment diets did not significantly ($P>0.05$) influence the fat, protein, lactose and SNF contents in goat milk. Milk yields and dry matter intakes were also not affected ($P>0.05$) by different treatment diets. Inclusion of amaranth seed powder into different treatment diets did not cause a significant change in the fatty acid profile and the cholesterol content of milk fat compared with the control. However, there were markedly high concentrations of conjugated linoleic acid (CLA) and, poly un-saturated fatty acids (PUFA) in milk fat of all treatment groups as well as in the control group, compared with the CLA concentrations observed in the literature. In addition, tested feed rations had no significant effect ($P>0.05$), on the body weights of the animals and the tested blood serum parameters compared to the control. Results reveals that incorporation of amaranth seed powder into the diets of milking goats, may not be useful when the goats are fed on comparatively high levels of natural forage, milling by products of black gram and rice polish. However, combinations of feed ingredients used in the diets have favorable effects on milk fatty acid composition especially on CLA without negative effects on animal performance.

Key words: Amaranth seeds, Dairy goats, Milk parameters, Blood serum parameters, Dry matter, Intake, Body weigh

04. CONSTRUCTION OF COMPOSITE VEGETABLE PRICE INDEX USING MODIFIED FACTOR ANALYSIS

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Abstract.

This study introduces a modified factor analysis approach to develop a composite vegetable price index. The new method uses scaling by dividing the original variables with its mean, a specific weight for each individual indicator variable and the index assigns a specific numerical value to prices of vegetables for a given month. Initially monthly wholesale prices of nineteen vegetable were considered. As some vegetable prices were highly correlated, ten representative variables for highly correlated variables were retained based on variable-cluster analysis and correlation analysis. Green Beans, Leeks, Cabbage, Tomatoes, Brinjals, Pumpkin, Cucumber, Luffa, Ash Plantains and Green Chili were the indicator variables considered in the index building process. Initially, the grouping pattern in the data was identified through a Preliminary Factor Analysis. This resulted in a single factor explaining a substantial amount of the total variance. The original variables were divided by their means to scale the variables. The weight corresponding to a particular indicator variable was defined by squaring the Eigen vector coefficient of the given variable of the first Principal Component. Then the scaled variables were weighted and used in the final Factor Analysis. A single factor explaining 69.8% of total variance was selected as the composite index. First, the Vegetable Price Index was defined as a linear function of the composite index. Then it was converted into a function of original indicator variables by summarizing constant terms to make it easy to update. Cronbach's alpha was used to verify the internal consistency of the indicator variables. Scaling in mean and weighting improved internal consistency of the variables. Seasonal ARIMA method was used to fit and forecast the index and the fitted model was ARIMA(2,1,1)(1,1,1)[12]. Standard Error (SE), Akaike information criterion (AIC), Box-Ljung test, ACF, QQ plot and histogram for residuals were used as the selection criteria to determine the best forecasting model. Composite vegetable price index and its forecasting are major requirements for vegetable farmers, buyers and input suppliers to plan their business while minimizing post-harvest losses and to the Government to assist in various policy making and development activities.

Key words: Composite Index, indicator variables, vegetable price Index, weighted factor analysis, time series analysis

05. POTENTIAL OF ENDOPHYTIC BACTERIA TO MANAGE *FUSARIUM* SPP. CAUSING FUSARIUM WILT OF TOMATO AND BRINJAL CROPS GROWN IN SRI LANKA

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Abstract

Fusarium wilt caused by *Fusarium* spp. is an economically important fungal disease of tomato and brinjal production areas in Sri Lanka. The genus *Fusarium* contains many species comprised of endophytes, pathogens and saprophytes and is difficult to differentiate by morphological and physiological attributes. Therefore, molecular identification of species and subspecies of the causal fungi associated with *Fusarium* wilt of tomato and brinjal crops in Sri Lanka has become a prime concern as it aids in effective disease management. The control of *Fusarium* wilt of tomato and brinjal is difficult due to expression of field symptoms at the later stage of the crop growth and it shows limited effectiveness to synthetic fungicides and are not environmental friendly and economically viable. Biological control using endophytic bacteria is one of the alternative control methods. The present study was carried out with the objectives of isolation and molecular identification of causal pathogens of *Fusarium* wilt of selected Solanaceous crops (i.e. tomato and brinjal) cultivated in Sri Lanka, to isolate and molecular identification of endophytic bacteria isolated from healthy tomato and brinjal plants collected from wilt-infected fields and to assess the efficiency of endophytic bacterial isolates against *Fusarium* wilt causing pathogen/s under *in vitro* and *in vivo* conditions as bio control agents to reduce incidence and severity of *Fusarium* wilt disease. A total of 79 *Fusarium* isolates were successfully recovered from diseased stems of tomato and brinjal plants collected from the 90 plant samples from fields of Kandy, NuwaraEliya, Matale and Badulla Districts. Based on pathogenicity test, out of the 79 isolates, 19, 23, 31 and 6 *Fusarium* isolates were confirmed to be highly pathogenic, moderately pathogenic, less pathogenic and non-pathogenic, respectively. Based on molecular identification, causal pathogens of *Fusarium* wilt of tomato and brinjal of the present study were identified as *Fusarium solani* and *Fusarium oxysporum* and the presence of four formaespeciales of *F. oxysporum*, namely *F. oxysporum* f.sp. *lycopersici*, *F. oxysporum* f.sp. *radices-lycopersici*, *F. oxysporum* f.sp. *trachephilum* and *F. oxysporum* f.sp. *eustomae* were confirmed. All the isolates of *F. oxysporum* f.sp. *lycopersici* identified in the present study belong to Race 1. This is the first report of molecular identification of species, formaespeciales and races of *Fusarium* wilt from major tomato and brinjal cultivation areas of the four districts in Sri Lanka, considered in the study. Twenty six out of the 30 bacterial endophytes isolated from stems of healthy tomato and brinjal plants collected from four Districts were Gram negative. The 30 isolates were tested *in vitro* for antagonistic effect against *Fusarium* species. The six isolates coded as E2, E7, E8, E10, E24 and E25 were found to be highly antagonistic (50- 67%) against *F. oxysporum* f.sp. *lycopersici*, *F. oxysporum* f.sp. *trachephilum*, f.sp. *radices-lycopersici*, and *F. solani*. Based on 16S rRNA gene sequence and homology search results, the Endophytic bacterial isolates were identified as *Pseudomonas geniculata* strain (E2), *Pseudomonas* sp. strain SB 904 (E7), *Delftia suluhatensis* (E8), *Stenotrophomonas maltophilia* strain ATCC 13637 (E10), *Stenotrophomonas pavani* strain ICB 89 (E24) and *Bacillus velezensis* strain C19 (E 25) were potential antagonists of *Fusarium oxysporum* f.sp. *lycopersici* and *Fusarium solani*. This is the first report of endophytic bacteria isolated from healthy *S. lycopersicum* and *S.*

melongena exhibiting *Fusarium* wilt suppression potential on tomato and brinjal plants in Sri Lanka. Three out of six antagonists were further evaluated *in vivo* against *F. oxysporum*. Application of the three endophytic bacteria as talc-based formulations to *Fusarium* infested soil at the time of transplanting as a soil treatment (15 g/ plant hill) or as a combination of seed and soil treatments showed the least disease incidence and severity compared to those when applied as seed treatment (10 g /kg of seed) alone. Present study identified *Pseudomonas geniculata* and *Bacillus velezensis* as promising endophytic antagonists for management of *Fusarium* wilt disease caused by *F. oxysporum* and *F. solani*.

06. ROLE OF GOVERNANCE AND INSTITUTIONAL ARRANGEMENT IN STRENGTHENING RESILIENCE TO SHOCKS AND STRESSES TO LIVELIHOODS IN MINOR IRRIGATION SYSTEMS

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Abstract

The village tank or Minor Irrigation System (MIS) is a man-made lake or pond which has been constructed by local people, with indigenous skills from ancient times in Sri Lanka, to fulfill food security needs of successive generations under water scarcity conditions. It is expected that climate change would add a new dimension to the problem of water scarcity in these MIS. Moreover, a significant portion of farmers in MIS are one of the most vulnerable community groups experiencing many difficulties due to severe seasonal or year-round absolute water shortage that affects their livelihoods. It has been reported that the struggle of farmers of MIS against rising scarcity of water and land resources is primarily due to issues of governance. In order to address this problem, the resilience of the vulnerable communities needs to be enhanced through smart investments and appropriate adaptation strategies. Introducing a solid and functional system for operation and maintenance of MIS would be a “no-regrets adaptation intervention” which will directly contribute to the national struggle to cope with variations of climate. In the above context, this study was conducted to review evolution of MIS governance process from ancient time to present; review existing regulations with regard to MIS development and management and map institutions which are responsible in implementing the regulations; identify MIS governance issues that need to be addressed; examine farmers’ requirements to make their livelihood resilience and propose possible improvements to MIS governance and institutional arrangement. Literature review was done to identify institutional reforms that has been taken place in MIS by contrasting those observed during pre-colonial and colonial periods with those after the independence. Literature and legislation review and Key Informant Interviews (KII) were conducted to map multi-sectorial institutional arrangement. Furthermore, information was collected through literature review and KIIs to analyze governance process in MIS using 91 variables under ten criteria. Since there is no well-established method for assessing the resilience of the farmers in MIS, a framework and methodology was developed to assess resilience and factors determining the resilience of livelihoods in MIS. A structured questionnaire survey was carried out among 188 households belonging to eight Farmer Organizations (FOs) in 16 MIS located in three Agrarian Service Divisions (ASD) in the IL3 agro-ecological region in Kurunegala district and direct observations were made to examine conditions of tanks. Using information collected from the

household survey, an empirical equation was derived to quantitatively measure the resilience of MIS. The results showed that there are more than ten institutions engaged in the development and management of MIS as at present. Department of Agrarian Development (DAD) and Provincial Irrigation Department (PID) are the main institutions which govern the MIS along with farmers' organizations (FOs). Other multiplicity of agencies plays a supportive role, operating independently of each other with very little coordination. The DAD as a department of the line ministry, under the Central Government with necessary legal enactments and regulations has a major role to play in governing the MIS compared to the PID. Although the PID of NWP has enacted regulations in 2014 to address concurrent issues in MIS, it does not have the required technical know-how, resources as well as an institutional arrangement to manage the MIS. One of the most complex issues of the governance is the lack of clarity of functional authority between the DAD and PID. In addition, the coordination between these two institutions and the farmers at the local level is poor. Using the empirical equation derived from the study, the resilience of MIS was quantitatively determined. The results showed that resilient component of each MIS as well as FO is fluctuating around the mid value (0.5), implying that there is adequate space to enhance the resilience of farming in MIS by introducing and adapting various risk management strategies. The institutional contribution including trust of farmers on FOs, office bearers and the agency officials are some of the key factors, which determine the resilience of farming in MIS. It is recommended to form a nested organization at the cascade level (e.g. Federation of FOs) with necessary legal backing to make them empowered to govern the MIS more effectively. Furthermore, capacity of the tank, tank conditions, water conservation farming measures and farmers' accessibility to support services were found to be major factors which determine the resilience of farming in MIS. Therefore, to enhance the resilience, it is suggested to introduce water saving cultivation measures/technologies, strengthen the FOs and develop access to market facilities.

2019-PhD

07. INVESTIGATION OF INTERRELATIONSHIPS AMONG SOCIOECONOMIC, HYDRO CLIMATIC AND FISHING PARAMETERS IN VICTORIA, SORABORA AND ULHITIYA RESERVOIRS AND THEIR IMPLICATIONS ON RESERVOIR FISHERIES MANAGEMENT

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Abstract

Sri Lanka possesses around 290 000 ha of freshwater bodies which indicates the tremendous potential existing for culture based fishing, processing and marketing leading to employment generation and poverty alleviation. To obtain maximum sustainable yield of an artisanal fishery it is essential to have a clear knowledge and understanding of the underlying fish population dynamics, species diversity and their seasonal fluctuations with hydro climatic factors and involvements of fishing community and management. Three randomly selected perennial reservoirs in Sri Lanka namely Victoria (major), Sorabora (minor) and Ulhitiya (major) were used to investigate the socio economic issues of the fishing communities and interrelationships among hydro climatic factors and fish yield. A rapid appraisal was conducted on a total of 368 fishers twice in January, 2014 and December, 2015 to investigate the socio-economic status and issues of fishing communities and their perceptions and involvement in fishery management. A pre-tested questionnaire was used to carry out the survey, in order to gather the required socio-economic information of fishers and information on management aspects of the aquatic resource. Issues related to respective fishery and fisheries organizations were recorded by participating in monthly meetings of the three Organizations during a period of two years. Chi-square analysis revealed that the three reservoirs were significantly different with respect to distribution of education level of fishers, engagement in fishing, level of savings, living standard, boat licensing and net registration, attending monthly meetings and awareness programs, receiving subsidy for gill nets and boats, income distribution and their perceptions such as usefulness and participation in fisheries organization and compliance to rules and regulations. Principal Component Analysis on socioeconomic variables resulted in seven principal components (PCs), representing organization strengthening attitudes (PC1), licensing & registration (PC2), commitment to fishery management (PC3), livelihood (PC4), fishing effort (PC5), and receipt of loans and subsidies (PC6), that explained 57.9 % of the cumulative variance. Variable grouping into uncorrelated PCs revealed lack of effectiveness of current management efforts and the need for innovative intervention strategies for better fisher involvement in fishery management. Further investigation towards unlawful fishing aspects prevailing in the reservoirs revealed that characteristics of fishers such as frequent consumption of alcohol, non-willingness to organize into a Fisheries Organization and noncompliance with fisheries regulations were significantly associated with engagement in illegal fishing in all the three reservoirs ($p < 0.05$). The fishers holding positions in the Fisheries Organization and/or voluntarily participating in official raids were found to be significantly less prone to engage in illegal fishing activities in Victoria ($p < 0.05$). In Ulhitiya, part time fishers and those not obtaining license and registration of boats and gear were significantly associated with illegal fishing ($p < 0.05$). Tendency for unlawful practices was greater among non-school goers in Sorabora and Ulhitiya ($p < 0.05$). Training programs conducted by NAQDA during the study period were effective in reducing illegal fishing only in Sorabora community ($p < 0.05$). The hypothesis that 'alcohol consumption of fishers has implications on fisheries management' was also examined. According to ANOVA procedure, fishers that consumed alcohol rarely (<3 times/month) had greater savings and significantly higher mean daily income (Rs. 1 260.00) compared with daily drinkers (Rs.

841.00). Chi square analysis showed that the negative association between alcohol consumption and living standard was significant only in Sorabora reservoir ($P < 0.05$). Smoking was significantly associated with alcohol consumption in all three reservoirs. Regular users of alcohol exhibited lower tendency to comply with regulations (e.g. boat registration) in Victoria and Ulhitiya. Holding positions in the fisheries organization, participation at trainings programmes, and attending monthly meetings regularly were negatively associated with alcohol consumption of fishers only in Victoria ($P < 0.05$). In Ulhitiya, fishers who voluntarily participated in Government operated raids were less prone to consume alcohol. Thus management measures formulated regarding alcohol use must be specific to individual fishing communities. A separate population dynamics study was carried out in the three reservoirs to determine the temporal variations of hydro climatic factors and catch and effort statistics. Catch and effort data were collected from January, 2014 to December, 2015 by visiting every landing site of the three reservoirs twice a week. Individual catches of 20 full time fishers/day/reservoir were examined for weight of the catch (kg). Hydro climatic data were extracted from relevant Government authorities. Species diversity of the catch was estimated using Shannon wiener diversity index. Receiving 1 mm of rainfall in the catchment area had resulted in increase of water level by 19.3, 0.9, and 1.1 cm in Victoria, Sorabora and Ulhitiya reservoirs, respectively ($P < 0.05$). A statistically significant seasonal variation was clearly evident for rainfall, water level, catch (of individual species) and effort statistics, catch diversity and income of fishers in all three reservoirs ($P < 0.05$). The water level and rainfall were responsible for only $< 15\%$, $< 25\%$ and 50% of the variation in catch statistics in Victoria Sorabora and Ulhitiya, respectively. Significant non-uniformity of monthly catch distribution was shown throughout the year ($P < 0.05$) for tilapia and carp species which dominated the catch ($P < 0.05$). Rise of catch per unit effort (CPUE) by extra 3kg of catch per boat would induce launching of extra one boat in Victoria and Ulhitiya while Sorabora needs extra 4kg of catch per boat to occur the same. Present species selectivity and economic benefits of gill nets of various mesh sizes were also critically evaluated. The total catch per net (CPUE) varied significantly according to the mesh size of gill net in every reservoir. The most popular gill net in all three reservoirs was of mesh size 8.9 cm. The highest catch diversity and economic returns were obtained by nets of mesh size 12.7cm for Victoria and Sorabora, and 11.4 cm for Ulhitiya reservoirs. Thus fishers must be educated on benefits of using mesh sizes larger than 8.9 cm. Based on the scientific evidence revealed by this study, appropriate revisions of the current management strategies and fisheries regulations with reservoir specific innovative interventions are recommended to achieve maximum sustainable yield in inland reservoirs.

08. ASSESSING CLIMATE RESILIENCE OF MAIZE (*ZEA MAYS* L.) AND MUNG BEAN (*VIGNA RADIATA* (L.) R. WILCZEK) AND INCREASING THEIR ADAPTATION CAPACITY TO LONG TERM CLIMATE CHANGE ON UPLAND CROPPING SYSTEMS IN SRI LANKA

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Abstract

Increasing temperatures pose a significant threat to crop production in the tropics. Understanding the magnitudes of this impact and development of adaptive measures are therefore important. The objectives of the present study were to determine the responses of maize (*Zea mays* L.) and mung bean (*Vigna radiata* (L.) R. Wilczek) to increasing air temperature (T_a) and to test a selected combination of agronomic management packages and intercropping as climate adaptation systems (CAS) aimed at decreasing essential inputs such as water, synthetic pesticides and inorganic nitrogen (N) fertilizer. The study was conducted under natural field conditions over four consecutive seasons from *maha* 2012/13 to *yala* 2014 at five locations (Rahangala, Peradeniya, Kundasale, Mahalluppallama and Killinochchi) with maize and three locations (Kundasale, Mahalluppallama and Killinochchi) with mung bean. The treatments included the current recommended management practices by the Department of Agriculture (T_1), mulching with current recommended fertilization and crop protection practices (T_2), mulching with an integrated pest management (IPM) package with recommended fertilizer management practices (T_3), mulching and IPM with modified nutrient management which provided 25% of the N requirement as organic manure (T_4) and an intercropping system (T_5). The observed variation of phenology, growth and yield formation of crops were attributed primarily to the crops' responses to the mean seasonal temperature variation across the sites. In maize, the rate of progress to 50% flowering and maturity showed a positive linear relationship with mean location temperature (T_a). Total biomass at 50% flowering ($TBM_{50\%}$), Total biomass at harvest (TBM_h) and yield showed significant second order polynomial relationships with T_a in both seasons. Variation of above parameters in the sub and supra optimal phases along the polynomial response curve per unit increase of T_a revealed that gain was lower compared to loss. The observed relationships of leaf area index at 50% flowering ($LAI_{50\%}$) with $TBM_{50\%}$, TBM_h and seed yield demonstrated the importance of an optimum LAI during early vegetative stage. In mung bean, the higher temperatures accelerated the progress towards flowering but the total crop duration was not always affected by the temperature variation among sites. $LAI_{50\%}$, $TBM_{50\%}$, TBM_h and yield showed decreasing linear trends with T_a in *yala* but not in *maha*. Among the yield components, the number of pods per plant (PN) showed highly-significant positive correlations with yield in both seasons. Significant positive correlations were observed between vegetative parameters (i.e. $LAI_{50\%}$, $TBM_{50\%}$ and TBM_h) and PN in both seasons. Analysis of yield responses to seasonal means of minimum (T_{min}) and maximum (T_{max}) temperatures showed that the influence of T_{max} was greater on seed yields of both crops. Therefore, even though changes in both T_{min} and T_{max} are taking place with climate change, T_{max} will have a greater influence on yield determination in a future climate. Unlike plant growth, total plant nutrient uptake and leaf nutrient concentrations did not show clear relationships with the MLT in both crops. However, N, P and K uptake rates per unit root dry weight varied as a polynomial function with T_a in maize. A decreasing trend of soil N across the temperature gradient was observed in both crops. Soil K content increased with T_a in the soils where maize was grown. However, a clear relationship was not observed with soil P in both crops. As observed in growth and yield, it was confirmed that the replacement of N by 25% with

organic manure did not show a negative impact on soil and plant nutrient contents especially in latter seasons. The advantage of intercropping maize and mung bean as opposed to growing them separately as monocrops both in terms of yield and economic advantage was clearly shown by the calculated intercropping indices, Land Equivalent Ratio, Actual Yield Loss and Monetary Advantage Index. The rates of yield decline at supra-optimal temperatures in intercropped maize and mung bean were only 48% and 27% of the rates of decline of their sole crop yields. This indicated that maize and mung bean are more resilient to increasing temperatures in the supra-optimal range when they are grown as intercrops as compared to them being grown in sole crops. The calculated intercropping indices showed an inverse second-order polynomial pattern of variation with temperature showing that, even though the crop yields declined due to the adverse impacts of increasing T_a above the optimum temperature (T_{opt}), the advantage of intercropping increased at supra-optimal temperatures. Thus, present work showed that components of the tested CASs, namely, mulching, IPM and partial replacement of inorganic N with organic manure, increases the resilience of upland cropping systems to increased growing temperatures as induced by long-term climate change. Therefore, they could be promoted among smallholder farmers in Sri Lanka and in the tropics, in view of their long-term environmental benefits and contributions to sustainable agriculture in a warmer and drier future climate.

Keywords: Climate adaptation systems, Temperature response, Mulching, Reduced N supply, Inter cropping

2020- PhD

**09. MORPHOLOGICAL, BIOCHEMICAL AND MOLECULAR
CHARACTERIZATION OF FRUITS AND RAPID MULTIPLICATION OF FIVE
SELECTED BAEL ACCESSIONS [*Aegle marmelos* (Lin.) Correa]**

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Abstract

The present study addressed the need of filling the knowledge gap in the process of developing bael [*Aegle marmelos* (Lin.) Correa] as a lucrative horticultural crop in Sri Lanka. The objectives of this study were to assess the fruit morphological diversity, optimize the DNA extraction and PCR protocols, assess the genetic diversity using SSR and ISSR markers, assess the bioactivity and phytochemical profiles of the fruit pulp and establish a micropropagation protocol for field grown trees of bael. The elite trees were selected by the Fruit Crop Research and Development Station (FCRDS) of the Department of Agriculture, Sri Lanka based on a nation-wide survey. The five elite trees (i.e. accessions), *Beheth Beli* (BB), *Mawanella* (MA), *Paragammana* (PA), *Polonnaruwa Supun* (PS) and *Rambukkana* (RA) selected in that survey were used as the experimental material in the present study. PS and RA produced the biggest fruits. PS also owned significantly least number of seeds that are also small and sterile. RA possessed the darkest flesh with the highest Chroma. RA and PA also got the highest pulp percentage, thus could be considered as the best fruit bearing trees. The modified CTAB method yielded a higher amount of DNA than commercial kits, without conceding the quality. The inclusion of spermidine at the rate of 0.8 μ M improved the efficiency of PCR by inhibiting polyphenols. The polymorphic SSR and ISSR markers revealed that PA, MA and PS are genetically similar at 98 % of Nei's genetic distance. The FRAP and DPPH assays revealed that the fruit pulp of accession PA has the highest antioxidant capacity demanding further studies. The bael fruits extracts can prevent the DNA nicking caused by free radicals through scavenging effects. At 5 mg/ml of fruit extract, RA demonstrated the highest inhibitory effect on DNA nicking and all the accessions demonstrated detectable inhibiting activity under 2.5-5.0 mg/ml of fruit extracts. The antibacterial activity of ethanol and water extracts of bael demonstrated that in general bael possesses similar inhibition against *Escherichia coli*, *Staphylococcus aureus* and methicillin-resistant *S. aureus* at 6,000-18,000 ppm which is comparable to an activity of gentamycin less than 0.045 mg/ml. The best sterilization method was found to be the washing of explants in a 2.5% fungicide solution for two hours. The leaf and twig explants gathered from monthly phenological stages revealed that the successful micropropagation is possible if the explants are harvested during April to May, immediately after the fruiting season of the plant. The full MS and 1/2MS media provided significantly similar performance in shooting as indicated by the measured parameters. The twig plants did better than leaf explants in shoot extension in which twig explants yielded 1.33 cm taller shoots. The MS medium supplemented with 1 mg/l of BAP generated the highest number of multiple shoots (6.20 shoots) and the most extended shoots (3.83 cm). The most successful rooting (60% success) was observed with full MS supplemented with 1 mg/ml NAA and 3% sugar. The success of acclimatization was 42% which is a higher accomplishment for a woody perennial containing higher amount of polyphenols.

Keywords: Beli, Micropropagation of bael, Antioxidant activity of bael, Antibacterial activity of bael, Genetic diversity of bael

**10. A COMPARATIVE POLYPHASIC STUDY ON VARIATIONS OF
MORPHOLOGICAL, MOLECULAR, REPRODUCTIVE FITNESS AND
PATHOGENICITY OF *Pratylenchus loosi* POPULATIONS OWING TO CHANGING
SOIL TEMPERATURES IN TEA PLANTATIONS OF SRI LANKA**

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Abstract

The Root-lesion nematode, *Pratylenchus loosi* Loof is the most economically important pest in tea in Sri Lanka. It requires optimal soil temperature range of 18-24 °C for their development. Under climate change scenario and inferior agricultural practices in Sri Lanka, unusual spread and damage levels of this nematode pest were evident in all tea growing regions which required specific nematode management strategies. Variations of morphological, molecular, reproductive fitness and pathogenicity of *P. loosi* populations in different agro-ecological regions in Sri Lanka viz. PL 1 (Cicilton, Balangoda), PL 2 (Delmar, Halgranoya), PL 3 (Hapugastenna, Ratnapura) PL 4 (Mahadowa, Passara), PL 5 (Nawalapitiya) and PL 6 (Richiland, Deniyaya) were investigated. The nematode population density was also monitored with rainfall, soil temperature and soil moisture in respective locations. Results revealed an increase in mean soil temperature above the optimal range resulting in different symptomological expressions and damage levels in tea. Contrasting deviations to the existing climatology graphs using data on rainfall, soil temperature and moisture and *P. loosi* populations in respective locations were seen in the six locations. Female morphometrics of *P. loosi* showed intraspecific variability and clustered in four groups in Principal Component Analysis where PL 1 and PL 5 were closely related while PL 3 and PL 6 clustered separately with exception of PL 2 and PL 4. Sequence analysis of D2/D3 expansion segments of the 28S rDNA gene of *P. loosi* populations revealed that PL 3 and PL 6 were closely related while PL 1, PL 4 and PL 5 were relatively distant. Sequences of ITS region of rDNA placed PL 3 and PL 6 in a single clade. The isolates PL 1, PL 2, PL 4 and PL 5 were relatively distantly-related and PL 2 and PL 4 were relatively distant from all populations. Molecular characterization further validated the closely related PL 1 and PL 5, PL 3 and PL 6 and distantly related PL 2 and PL 4 obtained from morphometric data. Interestingly, the symptomological expressions of all six populations PL 1- PL 6 behaved differently under field conditions. Studies with soil temperatures adjusted to 24°C, 28°C and 30°C in thermostatically controlled temperature tanks revealed highest *P. loosi* multiplication rate at 24 °C except PL 1 and PL 2 reduced with higher temperatures. PL 1 seemed highly virulent at soil temperature 24 °C showing significantly ($p < 0.05$) higher reduction in plant height (52.3%) and root weight (43.23%). PL 6 however, showed significantly ($p < 0.05$) higher reduction (58.67%) in shoot weight. Data confirmed that reproductive fitness was not always related with pathogenicity. Reproductive fitness of 61.2, 17.2 and 1.8 at soil temperatures 24 °C, 28 °C and 30 °C respectively showed high sensitivity of PL 4. At 28 °C, PL 2 exhibited a

significantly higher reproductive fitness. However, significantly ($p < 0.05$) higher reduction in plant height (59.41%), shoot weight (68.26%) and root weight (59.23%) were observed in PL 3, PL5 and PL 6 respectively. Reproductive fitness at 30°C in PL 2 was significantly higher. Significantly ($p < 0.05$) higher reduction in plant height (55.13%), shoot weight (59.60%) and root weight (57.68%) were observed in PL 5, PL5 and PL 4 respectively. While exhibiting intrinsic reproductive potential of *P. loosi* with soil temperature, high reproductive fitness did not always relate with high pathogenicity. All study populations except PL 3 and PL6 were genetically divergent and PL 2 and PL 4 were genetically different specific isolates which is corroborated with morphometrics of PL 2 and PL 4 populations being separated to clusters. Hence, morphometrically different and molecularly divergent *P. loosi* populations in tea in Sri Lanka with significantly different virulence and pathogenicity levels triggered by soil temperature variations were proven. This warranted appropriate nematode management and mitigation strategies in different tea growing regions.

11. EVALUATING THE PRODUCTIVITY AND STABILITY OF MAJOR RICE-BASED ANNUAL CROPPING SYSTEMS OF SRI LANKA USING

APSIM (Agriculture Production system SI Mulator)

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Abstract

Evaluating productivity and yield stability of crops in water-limited environments and under climate change scenarios is difficult in real field conditions. Modelling approaches can be used as alternative and efficient methods to evaluate the above. APSIM is a simulation model used to study the performance of crops under diverse management and environmental conditions. APSIM-oryza, APSIM-maize and APSIM-mungbean modules were parameterized and validated for widely grown Sri Lankan varieties, *i.e.* short (Bg300) and medium (Bg359) duration rice varieties, local variety Ruwan and hybrid variety Pacific for maize, and variety MI-6 for mungbean, across all three major climatic zones of the country. Historical rainfall data were analyzed to study the changes in rainfall onset and amount of rainfall received in those seasons. Moreover, validated models were used to evaluate the crop and water productivities (CP and WP, respectively) under different management and climate change scenarios. The APSIM-oryza module estimated the grain yield of rice under moisture-limited farmer-field conditions with a strong fit ($n = 24$, $R^2 > 0.97$, Root Mean Square Error (RMSE) = 484 kg ha⁻¹) under a wide range of conditions tested. APSIM-maize and APSIM-mungbean modules also estimated the grain yield with a strong fit for maize ($n = 37$, $R^2 > 0.95$, RMSE = 353 kg ha⁻¹) and for mungbean ($n = 26$, $R^2 > 0.98$, RMSE = 75 kg ha⁻¹). Historical weather data analysis revealed that the amount of rainfall received was higher when an early onset was occurred (63 % to 94 %) than that observed with a late onset. Moreover, an early onset resulted longer seasons than the late onset. Farmers regularly established rice crops 2–4 weeks after the rainfall onset. The APSIM- simulated results showed that the early and late onset coupled with early and late planting, had 33 % and 34 % higher CP, respectively, than when it was not coupled. When the onset of rainfall was delayed, dependency on supplementary irrigation for rice was predicted to be increased. Moreover, late planting with a late onset could result in higher variability in WP (4.3 ± 0.34 kg ha⁻¹ mm⁻¹) than that with an early planting and early onset (4.4 ± 0.12 kg ha⁻¹ mm⁻¹), even though the mean WP would be similar. The WP (24 %) and CP (10 %) of rice were greater

in Alternate Wetting and Drying (AWD) condition in model simulation than those in continuous flooding. It is predicted that the WP of rice-based farming systems could be increased by over 65 % when maize or mungbean extent was increased in water-limited conditions. The most efficient crop combinations to maximize net return were estimated as the diversification of land with 50 % rice and 50 % mungbean sole crops, or 25 %, 25 % and 50 % with rice, maize and mungbean sole crops, respectively. The model simulated that the CP negatively affects the yield stability of rice (33 %) in *Yala* season, and maize (30 %) and mungbean (32 %) in both seasons with changing climate at the end of the century in all three climatic zones, with a greater risk in the Dry Zone. In conclusion, the parametrised and validated APSIM modules for rice, mungbean and maize showed promising results and could be used in future predictions. Timing of rice planting should be adjusted based on the forecasted rainfall onset to harness the maximum potential of available natural resources. Access to supplementary irrigation with AWD irrigation also increased the stability of grain yield, CP and WP irrespective of the onset of rainfall or time of crop establishment. Selecting best crop combinations can increase the CP, WP and income. As the crop growth and grain yield could be adversely affected by climate change, precautions may take to maintain the stability of crop production.

12. INFLUENCE OF PHYSICO-CHEMICAL PROPERTIES OF BIOSORBENTS ON HEAVY METAL REMOVAL FROM INDUSTRIAL WASTEWATER

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Abstract

Heavy metals present in industrial wastewater play a major role in the degradation of surface water quality and can cause significant human and ecosystem health impacts. Chemical characteristics of heavy metals allow them to persist in the environment, in most instances only changing from one chemical state to another. This eventually leads to their accumulation in the food chain. Therefore, an efficient and cost effective treatment method is required for the removal of heavy metals from industrial wastewater before being discharged into the environment. Among the available treatment techniques, sorption, utilising agricultural waste is generally considered as an effective, economic and eco-friendly treatment option. Treatment efficiency of biosorbents primarily depends on the physico-chemical properties of the material. Accurately predicting the performance of biosorbents is important for developing biosorbent based treatment methods. Sorption performance mainly depends on material physico-chemical properties and experimental conditions applied to the system. Although the influence of experimental conditions on sorption efficiency is generally understood, the influence of physico-chemical properties of biosorbents has neither been systematically investigated, nor quantitatively assessed. This limits the use of biomaterials for water treatment using sorption. The innovative outcome of the present study is the approach developed to assess the sorption performance of biosorbents using sorbent physico-chemical properties in both, batch and continuous fixed bed columns. This enabled the quantification of sorption capacity, sorption kinetics and continuous fixed bed column breakthrough time using physico-chemical properties of the sorbent used. The study outcomes can also be used to assess the ability of different sorbents to remove heavy metals and provide the means to select sorbents with higher sorption efficiency in relation to a specific heavy metal species via the analysis of sorbent physico-chemical properties. Furthermore, the relative importance of each physico-chemical property in influencing the sorption performance can be identified. In order to develop the data matrix for the analysis, two biosorbents with distinct physico-chemical properties were mixed in specific weight ratios to obtain several combinations of physiochemical properties. This method was used to manipulate the inherent properties of the

biosorbents using mixtures to obtain a series of samples with significant variations in their physico-chemical properties. Pb^{2+} , Cd^{2+} and Cu^{2+} were selected for this study since these are commonly present in wastewater from textile and dye manufacturing industries. Physico-chemical properties were quantified while batch and column sorption experiments were used to generate data for the investigation of the influence of these physico-chemical properties on sorption capacity, rate of sorption and the performance of a continuous fixed bed sorption column. Mathematical models were developed to predict the influence of physico-chemical properties on sorption capacity and the sorption rate using Partial least square regression with k – fold cross validation. As the next step, an empirical equation was developed to estimate the breakthrough time of a continuous fixed bed sorbent column using parameters from the batch sorption studies. Though a range of physico-chemical properties influence Cu^{2+} , Cd^{2+} and Pb^{2+} sorption, their degree of importance was not equal. As identified in the current study, the key physico-chemical properties governing the sorption capacity of the selected biosorbents for all the three metal cations, are acidic surface functional groups followed by zeta potential. Among the acidic surface functional groups, Carboxylic plays a relatively prominent role in the sorption of Cu^{2+} and Pb^{2+} while lactonic are more important in providing binding sites to Cd^{2+} . Mathematical models developed to quantify the maximum sorption by biosorbents of Cu^{2+} , Cd^{2+} and Pb^{2+} were found to be reliable as indicated by the high coefficient of determination values. Influence of physico-chemical properties of sorbents on sorption kinetics was assessed using the pseudo second order kinetic constant. The present study developed predictive models to estimate pseudo second order kinetic rate constant values for the sorption of Cu^{2+} , Cd^{2+} and Pb^{2+} . The models were found to be reliable with the capacity to estimate the kinetic constant using sorbent physico-chemical parameters and initial metal ion concentration. Acidic surface functional groups were found to exert the highest influence while a high specific surface area with micropore structures was seen to reduce sorption rates as metals need time to diffuse into intraparticle structures to find active sites. It was found that breakthrough time for a sorbent in a column system can be predicted using the initial sorption rate in a batch system, with high predictability. Generally, a column is operated in an entirely different way when compared to a batch study. Hence, predicting breakthrough time based on the initial sorption rate can be used for the preliminary estimation for the designing of a laboratory column. Mathematical simulations developed to understand sorption in a column systems gave higher values for breakthrough time for Cu^{2+} and Cd^{2+} , while the simulated value for Pb^{2+} was found to be lower than the experimental value. The simulation provided a relationship to correlate the results obtained from batch experiments to continuous fixed bed columns. The simulation needs further refinements to enhance the accuracy of the prediction of breakthrough time of a continuous fixed bed sorbent column using batch experiment equations and physico-chemical properties of the sorbent. The outcomes of the study created new knowledge to enable the prediction of the performance of a sorbent in terms of heavy metal removal by using its physico-chemical properties. Such predictions would aid in creating treatment methods by modifying locally available biosorbents for enhancing the sorption performance.

13. VARIATION OF POPULATIONS OF ECONOMICALLY IMPORTANT PESTS AND YIELD, UNDER DIFFERENT CROP MANAGEMENT PRACTICES IN CINNAMON

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Abstract

Ceylon cinnamon (*Cinnamomum zeylanicum* Blume) is the popular spice with its own unique characteristics. Compared to other *Cinnamomum* species (*C. cassia* and wild species), Ceylon cinnamon consists of high medicinal effects which are helpful to control popular non-epidemic disease-like high cholesterol levels, diabetes *etc.* Although cinnamon is a hardy plant, its genetic diversity is high among plants, so cultivations are vulnerable to some pests and diseases which cause considerable yield losses. Therefore, it is important to maintain the sustainability of the perennial plantations in order to maximize the long term profits. The average annual production is around 500 kg/ha, which is very low compared to economical yield. It is important to introduce proper crop management practices to maximize the productivity of existing cinnamon cultivations in Sri Lanka: hence, this study was conducted with the objective of improving the productivity of cinnamon land through better management of the crops. The experiment was established in two locations at National Cinnamon Research & Training Center (NCRTC), Thihagoda and Yatiyana farmer field. Recommendations of cinnamon management by the Department of Export Agriculture were considered as control treatment (T1) and mamoty weeding was practiced in between two harvesting intervals with six months harvesting. Additional selective pruning practices in between two harvesting cycles were added in treatment 2 (T2). Mamoty weeding was replaced by slash weeding in treatment 3 (T3). Earthing-up was applied to manage wood boring moth (WBM) with all other practices applied in treatment 3 (T4). Bordeaux mixture was applied to manage rough bark disease (RBD) in treatment 5 (T5) with all other practices in T4. Treatments were arranged in randomized complete block design (RCBD) with three replicates (each plot consisted of 80 – 100 bushes). Occurrence and severity of WBM damage and RBD were recorded. Weed growth was monitored in one harvesting cycle of existing cinnamon fields. Soil invertebrate diversity and abundance were recorded in NCRTC field within one harvesting cycle. Soil moisture, soil pH, bulk density and soil organic matter were measured to assess the soil health of existing cinnamon field. Dry bark yield in four harvesting cycles in both locations and cost benefit ratios were calculated by using current costs and cinnamon prices. Damage incidences of WBM were recorded significantly low in T4 and T5 where earthing-up introduced in both locations. RBD was significantly low in T5 where Bordeaux mixture was applied in both locations. Weed biomass and soil invertebrate abundance were recorded significantly high in the treatments which consist of slash weeding. Percentage of beneficial soil invertebrate community for better soil health is significantly high and non-beneficial soil invertebrate percentage is significantly low in treatments where slash weeding was practiced. Soil moisture affected by the weeding method. Yield was increased with the time and it was high in the second year. Cumulative yield was significantly high in T5 where maximum numbers of agronomic practices were used in NCRTC field. Cumulative yield of all T3, T4 and T5 were high in Yatiyana farmer field. Total profit margin was higher in T3 and T2 respectively in NCRTC field and Yatiyana field. Annual profit in NCRTC field was increased in second year from T1 to T5. In order to maintain sustainability of existing cinnamon plantations, it is important to enhance the crop health and soil health of existing fields. The selected simple agronomic practices can help to maintain better crop and soil health. Even though increase of the number of agronomic practices, decrease the profit margin, annual profit is increasing in T5

where the highest number of agronomic practices was used treatment.

Key words: Cinnamon, yield, rough bark disease, wood boring moth, profit margin

14. DEVELOPMENT AND VALIDATION OF INTERACTIVE MATHEMATICAL EXPRESSIONS FOR BIOCHEMICAL TRANSFORMATION KINETICS

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Abstract

Biochemical transformation (BT) kinetics is a ubiquitous parameter in biospheres owing to multiple interactions among its biotic components of plants, animals, and microorganisms. The development and validation of universal equations describing all BTs is difficult. Kinetic models such as logistic growth equation, first order, Monod, and Michaelis-Menten, and their modifications are most commonly used models to understand the BT processes. This study was conducted to derive mathematical expressions to define stages of growth and decay, climatic influences, nutrition levels, media, pH, and ionic strength which can be applied to plant growth, microbial activities, and animal growth. To do so, six studies were conducted and secondary data from elsewhere were used to validate the new expressions. As the first study, equations were derived based on first order rate kinetics describing scaling-up of a laboratory scale up-flow anaerobic sludge blanket reactor. It resulted in fabrication of the second prototype reactor, having a total height 3.4 m, being optimum for kitchen wastes. Best is to examine formation of enzyme-substrate complexes, which is the basis of BT kinetics. Thus, the second study was conducted to develop a robust scheme based on unit productions of enzymes and reactants in cyclic events to comply with mass action law to form enzyme-substrate complexes. The developed formalism supports a successful application of Michaelis-Menten kinetics in all BTs of single parameters. It is an essential tool to overcome some challenging healthcare and environmental issues. In developing the formalism, the substrate defined as $[Product]^{3/4}$ and rate of reaction based on rate and time perspectives. It resulted two quadratic equations. First, represents a body entity that gave a useful relationship of enzyme, and second nutrients/feed, each giving $[enzymes]$ and $[enzyme-substrate complexes]$, simulating rate of reaction, $[substrate]$, and their differentials. By combining both values of quadratic equations derive a Michaelis-Menten hyperbolic. Proportionate rate of reaction from $[Enzymes]$ values of the quadratics resulted in another Michaelis-Menten hyperbolic. In between these two hyperbolic functions, un-competitive inhibitions exist, indicating metabolic activities and growth in terms of energy levels. We validated these BTs with examples applicable to day to day life. These enzymes derived from body entity can be mathematically related to cumulative values of pH, ionic strength, and temperature as power functions for different secondary experimental data. Cumulative temperature values were considered in obtaining the energy in terms of enthalpy, entropy and balances, because the cells are accumulated over time and they are always replaced in the body entity. The third study was conducted to develop an analytical procedure for applying Michaelis-Menten kinetics for the results of the first UASBR, to optimize the performance, manifesting non-

competitive inhibitions between growth phases. The fourth study also revealed that in determining Michaelis-Menten kinetic parameters by deducing phase changes of a leachate treatment bioreactor (LTB), the time for replacement of media could be predicted. The fifth study was conducted to determine the design and operational parameters, and mineralization rate of the LTB with the application of logistic growth kinetics. The sixth study revealed that simulation and prediction can be done fairly accurately using logistic growth equation. In observing the cyclic behavior of biochemical transformations, the concept of cumulative values has emerged to be a natural law. It was found that Monod kinetics, being an empirical equation cannot be applied in such analyses of cumulative values.

Keywords: Enzymes, First order, Logistic growth equation, Michaelis-Menten, Substrate

15. EFFECTS OF ULTRASOUND ON HOMOGENIZATION AND FERMENTATION KINETICS OF BUFFALO'S MILK

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Abstract

Buffalo's milk is the second most important milk type in the world after cow's milk and is typically processed into a variety of dairy products such as yoghurts, cheese, butter oil, etc. Fermentation of buffalo's milk faces some problems compared to the fermentation of cow's milk, owing to the differences in the composition and structure of the milk components, in particular milk fat and proteins. Prolonged fermentation time and low stability of the milk gel matrix are the crucial factors affecting the large-scale production of set yoghurts from buffalo's milk. Employing ultrasound under appropriate energy densities into fermented foods is an emerging technology, which has the potential to promote the fermentation process and gel properties of buffalo's milk. However, the appropriate ultrasonic conditions for the fermentation of buffalo's milk has not revealed to date. This study aimed at applying power ultrasound into buffalo's milk for improving the efficiency of related processes such as homogenization and fermentation. A comprehensive investigation was conducted to determine the optimum levels of ultrasound energy densities and the stage of application of ultrasound into buffalo's milk during fermentation with lactic acid bacteria. It is found that application of ultrasound in the range of 1123-2246 J mL⁻¹ energy density during the lag phase of growth of lactic acid bacteria enhanced the growth rate of bacteria, the activity of β -galactosidase and degree of lactose consumption. The fermentation time of buffalo's milk was subsequently minimized while the rheological properties of the set yoghurts were improved. The ultrasound-treated lactic acid bacteria appeared to have different rates of growth and metabolism compared to untreated counterparts. Using response surface methodology, the mathematical models have been developed to determine the effects of major processing conditions which influenced the fermentation process of buffalo's milk using ultrasound-treated bacteria. Optimum parameters for the growth temperature of lactic acid bacteria, the amount of bacterial inoculum used for the set-yoghurt production and the ultrasound energy densities applied for the bacteria were identified as 41.1 °C, and 0.1% v/v, and 1348 J mL⁻¹, respectively. Fermentation of buffalo's milk under the optimum conditions shortened the fermentation time by 33.6 min (13.5%), improved the gel firmness by 55.6% and reduced the syneresis by 3.4% (w/w) in buffalo's milk set yoghurts compared to untreated set-yoghurt samples. Further, ultrasound-

treated set-yoghurt samples exhibited a denser and more compact microstructure comprised of more branched and interconnected protein strands and milk fat compared to untreated samples. This study further investigated the effects of employing ultrasound into the buffalo's milk fermentation on the milk components, in particular, the milk fat, which has a direct influence on the quality of set yoghurts. Ultrasound was applied into buffalo's milk at different energy densities and the effects on the size, stability, and microstructure of the milk fat globules were investigated. It was revealed that ultrasonication with 1188 J mL⁻¹ energy density reduced the average volume-weighted mean diameter (D_[4,3]) of milk fat globules by 93% and increased the surface area by a factor of 8.5 compared to the native counterparts. Similarly, a higher zeta-potential was observed in ultrasonicated buffalo's milk compared to untreated milk indicating better stability of milk fat globules. In summary, the identification, quantification, and optimization of power ultrasound as an advanced process to improve the fermentation of buffalo's milk and to improve the gel properties of buffalo's milk set-yoghurt are the key contributions of this research work. For the first time, the overall fermentation profile of the ultrasound-treated buffalo's milk was revealed. The knowledge gained from this study can potentially be employed in the buffalo's set-yoghurt production to improve the process efficiency and product quality using ultrasound technology.

16. MOLECULAR CHARACTERIZATION OF BEGOMOVIRUSES INFECTING OKRA VARIETIES GROWN IN DIFFERENT LOCATIONS IN SRI LANKA AND DEVELOPMENT OF EFFECTIVE AND ECO-FRIENDLY APPROACHES FOR ITS' MANAGEMENT

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Abstract

Okra (*Abelmoschus esculentus*) has been grown as a major vegetable crop in all agro-ecological zones of Sri Lanka either as a home garden crop or at commercial scale. At present, okra production in Sri Lanka has been severely affected by okra yellow vein mosaic disease (OYVMD). Reports based on symptomatology and preliminary molecular studies have identified the causal agent of OYVMD as a begomovirus. However, in depth investigations on identification and characterization of the causal agent and determination of effective management strategies are a timely need. The major objectives of present study were to confirm the identity and characterize the causal agent/s of OYVMD at molecular level, to screen resistant varieties of okra available in Sri Lanka to OYVMD, to find out reliable methods to detect OYVMD in plant tissues at their early stages of infection, and to discover a set of non-chemical pesticidal and eco-friendly approaches to manage the disease. In order to confirm the identity and to get an insight of the molecular variability of causative agent/ agents, symptomatic leaf samples were collected from six different locations in Sri Lanka and total genomic DNA were isolated using a modified method developed in the present study. The extracted DNA was amplified using primers specific to begomovirus and beta satellite. The full-length genome of the DNA-A was PCR amplified and the amplicons of DNA-A from two samples representing each location were cloned, sequenced, and deposited in GenBank database. Based on the sequence analysis and according to ICTV guidelines for virus classification, two different types of begomoviruses; *Okra enation leaf curl virus* (OELCuV) and *Bhendi yellow vein mosaic virus* (BYVMV) were identified in

OYVMD infected plants but to amplify DNA- B was failed in any of the tested samples. Full length of betasatellite DNA in infected okra plant which were collected from each location was amplified with a pair of universal primers and they were cloned, sequenced, and deposited in GenBank. Sequence analysis revealed that the associated betasatellite as Bendi yellow vein mosaic betasatellite (BYVMB). Furthermore, leaf samples collected from infected okra plants showed positive results to dot blot hybridization using a digoxigenin labelled DNA probe, which had been prepared specifically to detect BYVMB. In the present study, a quantitative PCR (qPCR) assay was developed with primers specific to BYVMB to detect and quantify OYVMD causing agent based on symptom modulating satellite molecules. The method was tested to find out the relationship between symptoms and virus titre in range of severity of OYVMD symptoms. qPCR was able to detect the present of BYVMBs in apparently healthy plants growing in an infected field at a concentration which was not able to detect in end point PCR. Virus titre was also measured in different ages of leaves and different positions. qPCR was tested as a tool to screen the resistant okra varieties and quantify the virus based on copy number of BYVMB DNA in okra varieties subjected to different treatments. An attempt was made to identify resistant varieties to yellow vein mosaic disease of okra by screening eight different cultivars under field conditions in both yala, and maha seasons. The disease incidence was comparatively lower in maha season than in yala season. Most of the cultivated varieties reported higher disease incidence compared to hybrid varieties in both seasons. Furthermore, a field trial was carried out with the above eight varieties to study the effect of non-pesticidal treatments (neem leaf extract, salicylic acid), beneficial bacterium *Bacillus megaterium*, and insecticide (Thiocyclam hydrogen oxalate) against OYVMD. The plant response against different treatments was not uniform between varieties in both seasons. This result was further confirmed by qPCR assay by quantifying the virus based on copy number of BYVMB in okra plants exposed to different treatments. Finally, a study was conducted to understand the efficiency of an eco-friendly disease management package on reduction of OYVMD. Okra varieties, TV8 and Haritha were taken in this study and preliminary experiments were done in plant house conditions and later they were tested in field conditions with three crop management practices viz. an integrated pest management (IPM) package with non-pesticidal practices, adopting Department of Agriculture (DOA) recommendations, control without the non-pesticidal approaches or use of synthetic pesticides for crop protection. The IPM package tested in the study revealed as an effective management practice towards the management of virus diseases with higher yield. Activity of plant defense enzymes were quantified in above field grown infected okra tissues collected at their mid growth stage. The IPM treatment induces the activity of β -1, 3-glucanase enzyme, polyphenol oxidase, phenylalanine ammonia lyase, and peroxidase in okra crops.

Key words: Defense enzymes, Dot blot hybridization, Integrated pest management, Monopartite begomoviruses, qPCR assay, Resistant varieties, Yellow vein mosaic disease of okra.

17. DESIGN, DEVELOPMENT AND EVALUATION OF A POWER WEEDER FOR ROW-PLANTED PADDY

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Abstract

Rice is one of the major important crops which impacts the most people in the world especially in Eastern countries including Sri Lanka. Weed management is one of the major constraints in rice cultivation worldwide. Water management, biological strategies, manual, chemical and mechanical methods are commonly used weed controlling methods in rice cultivation. Most of weed controlling methods are not preferred by farmers due to higher water demand, low weeding efficiency, higher labour requirement, environmental and health issues. The mechanical method is the most preferable method despite absence of highly effective weeder for medium and large-scale cultivations. The effectiveness of existing power weeders is also low due to the associated rotary mechanism. Therefore, this research was aimed to introduce an appropriate lowland power weeder, especially for medium and large-scale rice farmers in Sri Lanka. The soil dynamics, crop and machinery interaction studies, comprehensive design calculations, fabrications, series of performance tests and modifications were carried out to achieve this goal. Newly designed Burial Type Lowland Power Weeder (BLPW) consists of power source, frame and separate mechanisms for power transmission, weed burying, turning/row changing, floating, manipulation and controlling which are facilitated to bare the activated load, burying the weeds, achieve the required tractive power, speed and machine control in road and field manipulation. In comparative performance evaluation, five weeding methods such as, Cono-weeder, modified "Asakura" wooden clog, rotary power weeder, newly designed BLPW and manual weeding (control) were evaluated. The newly designed BLPW showed, significantly higher field capacity (which is 8 times higher than the control), field efficiency and weeding efficiency. Further, it showed the lowest weed re-growth rate (23%) which is essential for sustainable weed control and moderately high-performance indexes. However, plant damage percentage, maximum tiller number and yield did not show any significant variations ($p \leq 0.05$) among different weed control methods assessed. Further, the new BLPW showed moderately high break-even point of 0.88 ha yr⁻¹, suggesting that it is appropriate for the medium and large-scale farmers. The cost of operation and the labour requirement of newly designed BLPW were 1/4th and 1/5th from the conventional manual weeding, respectively. Moreover, this BLPW showed low fuel consumption and power requirement representing 48% and 42%, respective reductions over the power rotary weeder. Besides, newly designed BLPW showed higher satisfactory field performances in practical field tests; 0.03 ha h⁻¹ effective field capacity, 83.25% field efficiency, 80% weeding efficiency, 6.34% damaged plants and 580 performance index, 22 maximum number of tillers and 6968 kg ha⁻¹ rice yield. Further, calculated cost for weeding was Rs. 7671 ha⁻¹ under the field test. Calculated fuel consumption, labour and power requirement were 0.503 L h⁻¹, 33 man-h ha⁻¹ and 0.319 kW, respectively. Interestingly, no ergonomic or mechanical defects were reported during the field test and it was easy to operate. Based on the above results, newly designed BLPW can be recommended for medium and large-scale rice farming.

Keywords: *Asakura wooden clog, burial type weeder, Cono weeder, manual weeding, mechanical weeding, rice cultivation, practical field test, rotary power weeder*

18. STUDY ON FLOWERING AND FRUITING PHENOLOGY, AND FLORAL BIOLOGY OF THE PARENTAL CULTIVARS OF TEA (*Camellia sinensis* L.) SEED GARDENS IN SRI LANKA

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Abstract

Flowering and fruiting phenological and floral biological attributes of the parental cultivars in Tea (*Camellia sinensis* L.) seed gardens in Sri Lanka were assessed. Aiming to utilize the information to plan and implement the seed productivity enhancement programmes, in order to fulfill the increasing demand for the improved seed materials as an adaptation measure for climate change effects. The study was conducted in a representative sample of three isolated tea seed gardens located in the estates of Rambukkanda (Ratnapura), Salawa (Hanwella) and Reucastle (Dehiowita) in Sri Lanka. Five major reproductive phenophases; Immature flower buds, Mature flower buds, Open flowers, Immature fruits and Mature fruits were assessed, using a pre-determined visual scale (0-5) monthly for a period of three consecutive years. Floral morphology, Pollen biology; Anther dehiscence, Pollen viability and Stigma receptivity were assessed in the floral biology study. Phenotypic diversity of the seed progenies were also assessed to estimate the approximate genetic diversity. The study on flowering and fruiting phenology revealed the synchrony and the intensity of reproductive phenophases in relation to the time, parental cultivars and rainfall pattern of the locations. The major flowering peak of the year occurred from September to December with an additional brief peak in July. Major fruiting peak (cropping season) occurred from April to August. Significant ($P < 0.05$) variations in the intensity of flowering and fruit set was observed among the parental cultivars. The profuse flower setters (TRI 2016, TRI 2022, TRI 2025, TRI 3055, KEN 16/3 and S 106) and fruit setters (TRI 2016, TRI 2022, TRI 2025, KEN 16/3 and S 106) were identified accordingly. Phenograms and a phenological calendar were formulated subsequently to streamline the seed collection and to facilitate the garden management. The taxonomical status reflected by the pistil related morphology could be compared with the phenological attributes of the parental cultivars. Whereas the cultivars closer to Assam types produce more seed yield than those closer to Cambod types, in an environment, where the Assam-Cambod hybrids are open pollinated to produce seeds. The longevity of the receptivity period does not affect the effective pollination period, as the stigma was receptive even before the opening of the flower and continued till the flower withered off. Moreover, the profuse fruit setters possessed linear stigma with comparatively larger receptivity area, in contrast to the moderate and low fruit setters exhibiting apical type stigma with comparatively smaller receptive area. Based on the outcome of the pollen biology and the phenotypic diversity assessments, pollen donor potential of the parental cultivars were determined. Cultivars with, High (TRI 2022, TRI 2025, TRI 3055); Moderate to high (TRI 2016, KEN 16/3, KP 204, S 106); Moderate (TRI 2027, TRI 3063) and low (TRI 3047) pollen donor potential were identified accordingly. Seven parental cultivars (TRI 2016, TRI 2022, TRI 2025, TRI 3063, KEN 16/3, KP 204 and S 106) exhibited comparatively higher germinability levels, whereas the other two cultivars (TRI 2027 and TRI 3055) exhibited moderate germinability levels. TRI 3047 did not set fruits (seeds) at all. Based on the overall results; four poly-clonal and six bi-clonal parental cultivar combinations, were identified for future gardens to ensure the enhanc

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19. EFFECT OF DIETARY SUPPLEMENTATION ON PRODUCTION PERFORMANCE OF LACTATING DAIRY COWS FED WITH TOTAL MIXED RATIONS (TMRS)

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Abstract

It is a well-known fact that poor feed management during early lactation has caused substandard milk production in temperate and tropical crossbred dairy cows. Series of experiments were conducted to assess the nutritional status in the sense of energy balance during the early lactating period of temperate and tropical crossbred dairy cows and suggest an appropriate supplementation strategy to overcome any identified energy imbalance. Thus, the first study was designed to assess the energy balance in temperate and tropical crossbred cows. Based on the results of the study, three (3) feeding trials were conducted to assess the effect of ruminal protected fat supplement on the production performance of early lactating dairy cows. In the first study, tropical and temperate crossbred dairy cows at post-partum, transition stage (i.e. early lactation stage), managed at two medium-scale farms were assessed for the nutritional status using their metabolic profiles. Data showed that serum beta-hydroxy butyric acid (BHBA), content of tropical crossbred cows (1.32 ± 0.11 mmol/L) and non-esterified fatty acids (NEFA) and urea contents of temperate crossbred cows (0.62 ± 0.15 mmol/L, 30.09 ± 2.60 mg/dL, respectively) exceeded the upper critical limit for determining the negative energy balance (NEB) in dairy cows. The results revealed that both tropical and temperate crossbred dairy cows at post-partum, transition stage suffer from NEB under the current feeding system used in low-country dry-zone and mid-country intermediate-zone. Accordingly, adaptation of energy dense feeding programs was suggested to overcome the NEB during the post-partum transition period of dairy cows. The first feeding trial was conducted to investigate the influence of rumen protected fat supplementation during early lactation period on tropical crossbred dairy cows. The experiment consisted 2 treatments (basal diet alone and basal diets with 200 g/cow/day rumen protected fat supplement). At the second week post-partum, the cows were randomly assigned for treatments ($n=6$) and fed accordingly during the 15 week post-partum period. The cows supplemented with rumen protected fat recorded higher ($P<0.05$) milk production until the eleventh week of lactation compared to those which did not receive fat supplements. As such, rumen protected fat supplementation resulted 132.38 L/cow higher ($P<0.05$) cumulative milk production during the fifteenth week compared to their counterparts (1,142 vs. 1,010 L/cow). Serum NEFA, BHBA, albumin, calcium and phosphorous contents of both treatments varied within their respective upper and lower critical limits for determining NEB in dairy cows. The benefit cost ratio (BC ratio) analysis of rumen protected fat supplementation confirmed the direct financial gains through increased milk production due to fat supplementation. The study recommends rumen protected fat 200 g/cow/day supplementation with TMR feeding during the early lactation period to increase the milk production and profits from tropical crossbred dairy cows in the dry-zone. The influence of rumen protected fat supplementation during the early lactation period for intensively managed temperate crossbred dairy cows was studied in the second feeding trial. The experiment was on a Randomized Complete Block Design where the cows ($n=12$) at 5 days post-partum were assigned to 3 dietary treatments (BMR alone, BMR with 250 g of rumen protected fat/cow/day and BMR with 350 g of rumen protected fat/cow/day) for 12 weeks post-partum. Fat supplemented cows gained BW throughout the experiment while the cows which were not given fat supplements lost BW until the sixth weeks of the lactation. Daily milk yield, cumulative milk

yield and milk fat content increased ($P < 0.05$) due to supplementation of rumen protected fat. Analysis of BC ratio confirmed that the supplementation rumen protected fat 250 g/day is more ($P < 0.05$) profitable. During the initial weeks of lactation, serum NEFA and BHBA contents exceeded the upper critical limit indicating that all cows suffer from NEB. Yet, rumen protected fat supplemented cows recovered from NEB prior to the cows in the control. The study recommends rumen protected fat 250 g/cow/day supplementation with TMR feeding until the 12 week of lactation for temperate crossbred dairy cows to increase milk yield, milk fat content, and to quickly recover from NEB thereby increasing the profits. The third feeding trial was designed to assess the influence of rumen protected fat supplementation during the early lactation period on intensively managed, high yielding, temperate crossbred dairy cows in the dry-zone. In the experiment, cows ($n=10$) were fed with one of the 3 dietary treatments (BMR alone, BMR with 250 g of rumen protected fat/cow/day and BMR with 350 g of rumen protected fat/cow/day) from calving until 8 week post-partum. Supplementation of rumen protected fats resulted in greater ($P < 0.05$) daily milk yield and cumulative milk yield during the experimental period. Analysis of BC ratio confirmed that the supplementation of rumen protected fat 350 g/cow/day is more profitable. That the serum NEFA and BHBA contents of fat supplemented cows fallen below the upper critical limit for determining the NEB, is an indication of achieving a positive energy balance prior to their counterparts. Hence, supplementation of rumen protected fat 350 g/cow/day with TMR feeding until 08 week of lactation is recommended to increase the milk yield, quickly recover from NEB and obtain greater profits from high yielding temperate crossbred dairy cows in the dry-zone. The research project concludes that 200, 250 and 350 g/cow/day of rumen protected fat could be recommended as an energy supplement to tropical crossbred cows (Sahiwal x Jersey), temperate crossbred cows (Friesians x Jersey) and high yielding temperate crossbred (Friesians x Jersey) cows, respectively. Recommended supplementation of rumen protected fat during the early lactation period with TMR feeding assures early recovery from NEB, increase milk yield and profits from temperate and tropical crossbred dairy cows in Sri Lanka.

20. PARAMETER ESTIMATION AND ASSESSMENT OF MODEL FIT FROM HIERARCHICAL POISSON MODEL WITH TWO DIFFERENT COMPETING DISTRIBUTIONS BY MARGINAL MAXIMUM LIKELIHOOD METHOD

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Abstract

The method of maximum likelihood estimation (MLE) was proposed for estimating the parameters of the Poisson-Gamma and the Poisson-Beta hierarchical models. The likelihood functions of the Poisson-Gamma and the Poisson-Beta hierarchical models contain more complicated integral parts that cannot be solved numerically. The Newton-Raphson algorithm with the crude monte carlo method was used to compute the maximum likelihood estimates of the parameters of the Gamma and the Beta distributions. Programmes for the algorithms to estimate parameters were written in R language. The initial values for the parameter estimation of the Gamma and the Beta distributions were obtained from the method of moments and the Fubini's theorem. The accuracy of the parameters estimated from the Poisson-Gamma and the Poisson-Beta hierarchical models was accessed by generating random samples from the Poisson-Gamma and the Poisson-Beta hierarchical models with the known parameters and fitting those sample data to relevant hierarchical models and checking the recovery of the known parameters from the fitted models. The percentage of prediction error was calculated as, $(| \text{The actual value} - \text{The predicted value} | / \text{The actual value}) \times 100$. The prediction errors were 4.0 % and 4.5 % for the parameters λ and μ , respectively for the Poisson-Gamma model. For the Poisson- Beta model prediction errors were 0.01 % and 2.44 % for the parameters λ and μ , respectively. Whiteleaf disease incidence data in sugarcane were collected from the Sugarcane Research Institute, Udawalawe. The data were collected from a field of Lanka Sugar Company (Pvt) Ltd, Pelwatte. We assume the white leaf disease data follows a Poisson distribution with the parameter λ . The estimates of λ assuming the Poisson-Gamma hierarchical model and the Poisson-Beta hierarchical model were 0.38 and 0.56, respectively. White leaf disease incidence of sugarcane data were not well fit to the Poisson-Beta hierarchical model ($p=0.0001$). However, the data were well fit to the Poisson-Gamma hierarchical model ($p=0.1447$). Therefore, the Poisson-Gamma model can be used to make further inferences of white leaf disease incidence of sugarcane for the specific field. In conclusion, the expected value of the white leaf disease incidence of sugarcane for the field of Lanka Sugar Company (Pvt) Ltd, Pelwatte was 0.38. This was the estimate of the parameter of the Poisson distribution (λ) from the marginal maximum likelihood method assuming the Poisson distribution parameter (λ) distributed as the Gamma distribution. The parameter μ of the Poisson distribution is the expected value and the variance of the Poisson distribution. Therefore, further inferences for the white leaf disease can be done with the completely specified Poisson distribution.

21. VARIATION OF POPULATIONS OF ECONOMICALLY IMPORTANT PESTS AND YIELD, UNDER DIFFERENT CROP MANAGEMENT PRACTICES IN CINNAMON

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Abstract

Ceylon cinnamon (*Cinnamomum zeylanicum* Blume) is the popular spice with its own unique characteristics. Compared to other *Cinnamomum* species (*C. cassia* and wild species), Ceylon cinnamon consists of high medicinal effects which are helpful to control popular non-epidemic disease like high cholesterol levels, diabetes etc. Although cinnamon is a hardy plant, its genetic diversity is high among plants, so cultivations are vulnerable to some pests and diseases which cause for considerable yield losses. Therefore, it is important to maintain the sustainability of the perennial plantations in order to maximize the long term profits. The average annual production is around 500 kg/ha, which is very low compared to economical yield. It is important to introduce proper crop management practices to maximize the productivity of existing cinnamon cultivations in Sri Lanka: hence, this study was conducted with the objective of improving the productivity of cinnamon land through better management of the crops. The experiment was established in two locations at National Cinnamon Research & Training Center (NCRTC), Thihagoda and Yatiyana farmer field. Recommendations of cinnamon management by the Department of Export Agriculture were considered as control treatment (T1) and mamoty weeding was practiced in between two harvesting intervals with six months harvesting. Additional selective pruning practices in between two harvesting cycles were added in treatment 2 (T2). Mamoty weeding was replaced by slash weeding in treatment 3 (T3). Earthing-up was applied to manage wood boring moth (WBM) with all other practices applied in treatment 3 (T4). Bordeaux mixture was applied to manage rough bark disease (RBD) in treatment 5 (T5) with all other practices in T4. Treatments were arranged in randomize complete block design (RCBD) with three replicates (each plot consisted of 80 – 100 bushes). Occurrence and severity of WBM damage and RBD were recorded. Weed growth was monitored in one harvesting cycle of existing cinnamon fields. Soil invertebrate diversity and abundance were recorded in NCRTC field within one harvesting cycle. Soil moisture, soil pH, bulk density and soil organic matter were measured to assess the soil health of existing cinnamon field. Dry bark yield in four harvesting cycles in both locations and cost benefit ratios were calculated by using current costs and cinnamon prices. Damage incidences of WBM were recorded significantly low in T4 and T5 where earthing-up introduced in both locations. RBD was significantly low in T5 where Bordeaux mixture was applied in both locations. Weed biomass and soil invertebrate abundance were recorded significantly high in the treatments which are consist of slash weeding. Percentage of beneficial soil invertebrate community for better soil health is significantly high and non-beneficial soil invertebrate percentage is significantly low in treatments where slash weeding was practiced. Soil moisture affected by the weeding method. Yield was increased with the time and it was high in the second year. Cumulative yield was significantly high in T5 where maximum numbers of agronomic practices were used in NCRTC field. Cumulative yield of all T3, T4 and T5 were high in Yatiyana farmer field. Total profit margin was higher in T3 and T2 respectively in NCRTC field and Yatiyana field. Annual profit in NCRTC field was increased in second year from T1 to T5. In order to maintain sustainability of existing cinnamon plantations, it is important to enhance the crop health and soil health of existing fields. The selected simple agronomic practices can help to maintain better crop and soil health. Even

though increase of the number of agronomic practices, decrease the profit margin, annual profit is increasing in T5 where the highest number of agronomic practices was used treatment.

Key words: Cinnamon, yield, rough bark disease, wood boring moth, profit margin

22. A BASELINE SURVEY OF CORAL REEFS AND GENETIC DIVERSITY ANALYSIS OF SELECTED CORAL SPECIES IN JAFFNA PENINSULA AND ITS MAJOR ISLANDS, SRI LANKA

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Abstract

Jaffna Peninsula, the most extensive lagoon system in Sri Lanka, features diverse marine habitats including mangroves, seagrass beds, salt marshes, sand dunes and coral reefs. It covers 182 mile coastal belt. Knowledge on status of coral reefs in Jaffna Peninsula is often limited, and genetic diversity studies of coral species never explored in Sri Lanka. Aim of this present study was to identify the diversity, distribution, and status of coral reefs underpinning the health of reef ecosystems. Baseline field surveys were conducted with point Line Intercept Transects (LIT) method to characterise the benthic features such as live hard coral (HC), soft coral (SC), nutrient indicator algae (NIA), recently killed coral (RKC), rocks covered with turf algae or coralline algae (RC), broken coral rubble (RB), sponges (SP), silt (SI), sand (SD) and others (OT). The percentage benthic categories were assessed based on the standard Reef Check methods at the islands of Karainagar, Delft, Punkudutivu, Mandaitivu, Kayts and the four northern coastal regions namely Point Pedro “Munai”, Inbarsitty, Thondaimanaru and Valithoondal. The Northern coastal line of Jaffna Peninsula has the average live coral cover of 48.5%. Islands have an average of 27% live coral cover. There was a higher percentage of standing dead coral covers of branching *Acropora* and large domes of *Porites*, *Goniastrea* observed at the Allaipiddy site in Kayts, next to Punkudutivu island. Corals of the Kayts, Mandaitivu, Delft and Punkudutivu islands were severely affected since the dead coral cover was high. Morphological identification of coral species was made based on the skeleton structures, corallite patterns, growth pattern of colonies and forms of corals. There were a total of 123 hard coral species and eight soft coral species identified throughout the survey sites in this study. They represent the 12 families and 43 genera. Among the morphologically identified hard corals, 46 species were first time recorded in the Sri Lankan territory from this study. There were nine species found to be difficult to distinguish morphologically, applied for DNA barcoding by using the mitochondrial cytochrome oxidase subunit I gene (COI) for confirmation of species. Morphological identification through traditional taxonomy and DNA barcodes were consistent for all samples up to genus level. A common phylogenetic tree was constructed using the Neighbor Joining method to verify the species which are closely related and morphologically cryptic. The overall maximum nucleotide frequencies observed for the sequenced samples were G (24.50%), C (19.24%), A (21.60%) and T (41.92%). Nucleotide pair frequency analysis of ten coral samples revealed that 368 of 500 sites (73.6%) were conserved, 132 of 500 (26.4%) sites were variable, 79 of 500 (15.8%) sites were parsimony informative, and 53 singleton sites were present, confirming the usefulness of mtDNA in species-level phylogenies in corals. All the successfully sequenced species belong to genus *Acropora*, *Montipora*, *Pocillopora*, *Galaxea* and *Echinopora* were confirmed with the barcoding and phylogenetic results parallel to the morphological identification. Thus, present baseline survey results and genetic diversity analysis significantly extended the knowledge and understanding of untouched biodiversity of reef building Scleractinian corals which would

support and develop conservation efforts to onslaught the declining biodiversity and threats of coral reef ecosystems in Jaffna Peninsula.

Key words: DNA barcoding, cryptic species, benthic coverage, phylogeny, coral degradation, turf algae

23. DEVELOPMENT OF A DIVERSITY AND BIONOMICS GUIDED MANAGEMENT SYSTEM FOR MELON FRUIT FLIES (DIPTERA: TEPHRITIDAE) IN SRI LANKA

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Abstract

Pumpkin, bitter melon, luffa, cucumber and snake gourd are some of the major cucurbits grown in Sri Lanka for local consumption and for export market. Several Melon Fruit Flies (MFF) are considered as the most destructive pest complex of these cucurbit crops. Therefore, this study was conducted to determine the abundance and diversity of MFF in three selected districts in Sri Lanka, namely Anuradhapura, Kurunegala and Kandy with a view of redesigning the management system recommended for MFF, considering the bionomics of the pest complex in agro ecosystems of the country. Three species of cucurbit infesting MFF namely, *Bactrocera cucurbitae*, *B. tau* and *Dacus ciliatus* with abundance of >86%, 12% and <1% respectively have been recorded in Sri Lanka. *B. diversa* has been recorded only from the pumpkin flowers. Cue-Lure parapheromone traps placed in selected locations in the above districts attracted four species of MFF, namely *B. cucurbitae*, *B. tau*, *B. caudate* and *B. diversa* and six species of Fruit Flies, *B. trilineata*, *B. nigrotibialis*, *D. caillantra* and *B. gaviza*, *B. dorsalis* and *B. correcta*. Furthermore, the Methyl Eugenol pheromone traps placed in above locations, attracted *B. dorsalis*, *B. kandiensis*, *B. correcta*, *B. zonnata*, *B. versicolor* and melon fly *B. cucurbitae*. (However, one of the MFF, *D. ciliatus*, recorded in these locations did not attract to Cure Lure and Methyl Eugenol traps). The Parapheromone Cue-Lure mass trapping at the rate of 1 trap/ha (100 traps/km²) as a management tool for MFF was deployed in three locations namely Pallekelle, Pitawala Yaya and Horticultural Crop Research and Development Institutes field in Kandy district. After six months of continuous trapping, MFF counts were significantly lower (χ^2 29.97; P<.0001) compare to the initial counts in Pallekelle field. The average temperature of 27 C⁰, relative humidity 70-85% and the presence of photoperiod Light: Dark - 9: 15h, the whole life cycle of *B. cucurbitae* completed within 17-18 days. The whole life of cycle *B. tau* was 14-16 days. *B. cucurbitae* egg lays during the first week of its emergence and the peak period was observed in third to fourth weeks with the higher amount of eggs. During the assessment average temperature and RH were 26.5⁰C and 82%. *B. tau* egg lays during the second week of its emergence and the peak period was observed in five to sixth weeks. The rate of parasitism of MFF observed in infested cucurbit fruits collected from Kandy, Anuradhapura and Kurunegala Districts was around 2% , <1% and 0% respectively. Cucurbit samples collected from farmer fields exposed to different insecticides were tested for residues of Acephate, Profenophos and Abamectin showed that some cucurbit samples contained residues of Acephate 75% SP and Acetamiprid 20% SP. Number of MFF attracted to a blend of Cue Lure: Methyl Eugenol (ME) (3:1) traps were significantly higher for *B. cucurbitae* (χ^2 84.2; P<.0001), *B. tau* (χ^2 43.1; P<.0001) and true fruit flies, *B. dorsalis*, *B. kandiensis* and *B. correcta* (χ^2 148.1; P<.0001). Hence, a mixture of CL: ME (3:1) can be used to attract more MFF for male annihilation programs. Therefore, continuous mass trapping MFF using Cue Lure: Methyl Eugenol (3:1) blended parapheromone, removal and destroy of infested fruit through Augmentorium, covering of fruits

in post set stage using breathable cloth material and application of protein bait for larger fields would help lower the MFF infestation (<5%). Fumigation (using liquid phosphine (ECO2FUME) -2% phosphine in 98% carbon dioxide w/w) at the rate of 1,400 ppm for 24h exposure found to be effective for post-harvest disinfestations of cucurbits from *B. cucurbitae* (eggs, young and old larvae stages) in export quality bitter gourd.

24. MONITORING FLOATING AQUATIC PLANTS AND ALGAE DISTRIBUTION AND ASSESSMENT OF BIOMASS IN BATTICALOA LAGOON USING REMOTE SENSING & GIS

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Abstract

Batticaloa lagoon, the third largest estuary in Sri Lanka is frequently affected by floating aquatic plants (FAPs) dominated by *Eichornia crassipes* and floating algae (FAG). This study was aimed at mapping the spatial and temporal distribution of FAPs and FAG in Batticaloa Lagoon using remote sensing and GIS and to explore the relationship with water quality and the LULC in lagoon surrounding. The primary objective was achieved via assessing temporal and seasonal distribution of FAPs and FAG along with LULC in the lagoon buffer zone (LBZ), developing relationships between field measured and satellite derived biomass to estimate the distribution of Green (GBM) and Dry (DBM) biomass of FAPs, detecting algal distribution using satellite image classification techniques, mapping the seasonal variability of selected water quality parameters and assessing the impact on the distribution of FAPs and FAG in both seasons and finally developing combined risk maps to identify the spreading of FAPs and FAG in relation to Water Quality Index (WQI) in Batticaloa lagoon. The study used cloud free Landsat and Sentinel 2A (S2A) images to detect FAPs and FAG to assess the temporal (1988-2016) and seasonal changes (2017-2018) using unsupervised classification. A buffer zone of 3 km was created around the lagoon to obtain the LULC distribution in the LBZ to study their influence on fluctuation of FAPs and FAG. Real time field measurements of biomass of FAPs were obtained in 12 locations in two week intervals for the period of March 2017 to February 2018. A number of band ratios and indices were developed using Landsat 8 (L8) and S2A images to establish relationships with field measured biomass to develop biomass distribution maps of FAPs in both seasons. Sub-pixel classification was used to identify the distribution of FAG based on the level of pixel reflection which indicated the algal coverage. Selected water quality parameters were measured at 30 sampling locations in 200 m inner lagoon buffer zone (ILBZ) in monthly interval from March 2017 to February 2018 to coincide with satellite images acquisition (near real time) to interpolate the spatiotemporal distribution of water quality. The impact of water quality on field measured and estimated biomass of FAPs and coverage of FAG were assessed to develop WQI in order to map and identify the risk areas on spreading of FAPs and FAG in relation to WQI of Batticaloa lagoon. The multi-temporal analysis revealed that the distribution of FAPs and FAG showed an increasing trend from (2.4 to 7.0 %) and (0.7 to 2.3 %), respectively from 1988 to 2016, while the extent of paddy lands and built ups were expanded and the vegetation and bare lands were declined in LBZ, simultaneously. Seasonal pattern of FAPs and FAG revealed that the distribution highly varies

between dry and wet seasons. The LULC analysis in the LBZ revealed that paddy (53 %) is the abundant land use in the study area and the cultivation is highly seasonal followed by built ups (39 %). Both have high impact on the distribution of FAPs and FAg in both seasons. Among 21 tested band ratios and indices, B3/B5 (Green/NIR) and B5/B4 (NIR/Red) of L8 images showed strong positive correlation with field measured GBM and DBM ($r^2=0.72$ and 0.61) in dry season and ($r^2 = 0.82$ and 0.69) in wet season, respectively. NDREI of S2A showed strong positive correlation with field measured GBM and DBM ($r^2= 0.78$ and 0.71) in dry season and B8/B4 (NIR/Red) and NDREI_Narrow ($r^2 = 0.68$ and 0.61), respectively in wet season. Seasonal variation of water quality of Batticaloa Lagoon depends on more than one physicochemical parameters of lagoon. Furthermore, field measured and estimated biomass of FAPs and spatial coverage of FAg showed significant correlations ($p<0.05$, $p<0.01$) with water quality of lagoon in both seasons. The developed WQI showed a strong inverse relationship with field measured GBM ($r^2 = 0.70$, 0.70) and DBM ($r^2 = 0.70$, 0.77) of FAPs in both seasons and with the coverage of FAg ($r^2 = 0.78$) in dry season. Biomass distribution maps of *Eichornia crassipes* relevant to WQI showed higher level of risk in Navithanveli and Kalmunai DS divisions, moderate level of risk in Manmunai South Eruvil Pattu and low level of risk in Manmunai Pattu and Manmunai Southwest Pattu DS divisions. High algal infestation ($>70\%$) was confined to Manmunai North, Eravur Town and Kathankudy DS divisions and moderate level of coverage (50-70 %) is at the locations confined to Eravur Pattu and Manmunai West DS divisions. LULC analysis showed that these locations are prone to urban and agricultural runoff discharges due to rapid urbanization and intensive agricultural activities. However, the sampling locations enriched with natural habitats were free from FAg. The study shows that the Landsat and S2A images have the potential to detect and map the level of risk in the spreading of FAPs and FAg which can be linked to WQI-LULC dynamics in the lagoon buffer zone.

25. EVALUATION AND COMPARISON OF THE NUTRITIONAL COMPOSITION OF SELECTED TRADITIONAL CEREALS, PULSES AND YAMS GROWN IN SRI LANKA

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Abstract

This study was conducted to determine the nutritional composition of selected locally available traditional cereals, yams and pulses grown in Sri Lanka. Further, it determines the nutritional composition of selected traditional cultivars/varieties with an emphasis on seasonal variation. A comprehensive compositional database of traditional and underutilized rice, cereals, pulses and yams is not available in Sri Lanka. Therefore, this study would be beneficial to obtain a general consciousness on the composition of traditional rice, cereals, pulses and yams available in Sri Lanka. Proximate composition, dietary fiber content, fatty acid profiles, mineral profiles and vitamin profiles of ten rice varieties, five cereal varieties, eight pulses varieties and four yam types were evaluated. Sample collection was done by collecting samples representing all agro-climatic

zones of Sri Lanka. Pooled composite dried powders of selected varieties were used for analysis. Yams contained the highest available carbohydrates compared to all the samples tested. However, yams were low in crude protein, dietary fiber and crude fat. Pulses were rich in ash in addition to proteins. Millet varieties analyzed were richer in ash and dietary fiber compared to rice varieties tested in the current study. Available carbohydrates in tested rice varieties were higher than in millet varieties tested. Foxtail millet contained richer crude fat content and fatty acid profiles compared to all the other samples analyzed and pulses were the best source of dietary fiber out of all the varieties tested. All the samples analyzed were rich in potassium while heavy metal content of all the commodities were remained below the harmful level to the human health. Improved rice varieties possessed higher contents of calcium compared to traditional rice varieties, while traditional rice contained higher iron content compared. Finger millet varieties analyzed were rich sources of calcium and manganese while foxtail millet varieties were rich in copper and zinc. Pulses are rich in iron while Angili ala was found to be a good source of sodium. The most abundant fatty acid present in rice varieties was oleic acid, while foxtail millet varieties tested were richer in both saturated and unsaturated fatty acids. Palmitic acid and linoleic acid were the most abundant fatty acids found in yams. All the commodities analyzed were rich sources of thiamin and riboflavin while fat soluble vitamin contents of tested varieties were very low compared to vitamin B1 and B2. Nutritional profiles of tested varieties proved that adding these varieties to the daily diet can meet RDA values successfully. Rice varieties cultivated in Yala season (2016) showed significantly higher nutritional value (except water-soluble vitamins) than rice cultivated in Maha season (2015) probably due to higher rainfall received in Yala season, environmental and climatic conditions. Further repeat studies are required to decide whether Yala season results comparatively more nutritious rice than in Maha season. This study can be used as a preliminary trial to conduct a new study to discover whether the nutritional composition of rice is affected by the seasonal variation.

Keywords: Cereals, Evaluation, Nutritional composition, Pulses, Traditional, Yams

26. ENVIRONMENTAL AND LIVELIHOOD IMPACTS OF DEDURU OYA DAM CONSTRUCTION AND WATER DIVERSION

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Abstract

Dam construction and water diversion have become a common feature of development in the world to receive multiple benefits. Yet the dams are criticized because of their negative impacts to the environment and to the society. Deduru Oya reservoir project in Sri Lanka is a large dam project commenced in 2014 with the objective of providing irrigation water to around 7000 ha of lands in Deduru Oya basin and around 4115 ha of lands in Mi Oya basin. The main objective of this study was to evaluate the social, livelihood and some environmental impacts of Deduru Oya dam construction. The status of resettlement program adopted in Deduru Oya reservoir project was studied addressing the legal framework for resettlement in Sri Lanka using literature survey and short interviews with relevant officials in the land office of the Deduru Oya Reservoir project. Moragahakanda reservoir project was also executed in parallel to the execution of Deduru Oya reservoir project. Since both are large dam projects, resettlement action plan of Moragahakanda reservoir project and its legal background was used to compare with that of Deduru Oya reservoir project to identify positive and negative aspects in two projects. The land use/ land cover in Deduru Oya reservoir area before inundation and within a 100 m buffer zone around the reservoir was assessed to identify the changes and its livelihood and economic impacts. Satellite imagery available in Google Earth was visually interpreted and land use/ land cover maps were produced for the purpose. To evaluate the social and livelihood impacts on resettled communities of Deduru Oya project, primary data were collected from Key Informant Interviews (KII) with the government officials (Irrigation Directors' Office, Kurunegala and Grama Niladhari officers of each resettlement site) and with a questionnaire survey on resettled communities (134 families from four resettlement sites). Secondary data sources include content analysis of documents on Deduru Oya reservoir project. Data were analysed to assess the social and livelihood impacts as the result of displacement. Livelihood vulnerability index was developed to compare the four resettlement sites. The stream flow changes in the downstream were analysed using flow data before and after dam construction at Rideebendi Ella anicut located 300 m downstream and with rainfall data from Batalagoda rain gauging station in the upstream. All the outputs were used to comment on the impact on Deduru Oya dam construction on the society and the environment. According to the analysis, Deduru Oya reservoir project has received relatively less scores compared to Moragahakanda project in terms of payment of compensation, resettlement process, resettlement planning principles and land acquisition guidelines. This shows that implementation of resettlement related procedures in Deduru Oya reservoir project has not achieved the same levels as that of Moragahakanda project. The Livelihood Vulnerability Index (LVI) is a useful tool to analyse the impacts on livelihood in a community affected due to development projects and it covers seven major components of livelihood vulnerability and address almost all possible ways of distresses upon the resettled community. According to the LVI, Karuwalagaswewa resettlement site brings the best opportunities to the resettled community to restore their livelihoods as it obtained least LVI value. However, as this resettlement site is located far from the original places of people and remote, the satisfaction level of the people who lives in Karuwalagaswewa was found to be the lowest. Though the LVI has the highest value in Ganawaththa resettlement site mainly due to lack of agricultural lands, the overall satisfaction among the resettlers is the highest due to availability of infrastructure and other facilities. According to the analysis, Deduru Oya reservoir has inundated about 1170 ha of total land extent which consists of 40% of paddy lands,

31% of coconut lands and 27% of forest lands. A total of 555.76 ha of paddy lands has submerged in the reservoir. The paddy yield loss was estimated as 2257.50 tons in 2014 Maha season due to the reservoir construction. Downstream flow of Deduru Oya stream has been considerably affected due to the dam. However, the water availability is high after the dam construction due to flow regulation by the reservoir. This benefit mainly the farmers in the downstream irrigation schemes such as Magalla irrigation scheme since water supply during dry season has increased after the dam construction. The study identified that the Deduru Oya dam construction has brought positive and negative impacts to the people and the environment. High spatial resolution satellite images available in Google Earth provided a better picture of the land use/ land cover changes in the area. Livelihood displacement followed by physical displacement of people and associated problems are evident in the study. Hence, further in depth studies on resettled communities and the downstream environment are needed to assess the long term recovery process and to bring support mechanisms to overcome the negative impacts.

2020- MSc

27. UTILIZATION OF INDUSTRIAL FRUIT WASTE: EXTRACTION, CHARACTERIZATION AND INCORPORATION OF PECTIN FOR VALUE ADDITION TO ICE CREAM

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Abstract

Lime and mango are extensively used in Sri Lankan food processing industries and considerable volumes of lime (65%) and mango (58%) wastes are thrown away. These waste possess significant quantities of pectin and therefore appropriate methods to extract pectin from both peels can serve as the means of valorization of fruit wastes and environmental protection leading to sustainable environment. Hence, the present study aimed to establish the optimal pH, temperature and time to obtain maximum yield of pectin from industrial lime and mango peel wastes using acid extraction method and the possibility to use them as fat replacers in frozen dairy dessert (similar to ice cream). Mango and lime peels obtained as wastes from fruit processing industries were dried at 60 °C, powdered into particle size of 0.425 - 0.850 mm and stored in metalized polyester bags (Gauge no 06) at ambient conditions for further use in the study. Proximate analysis was carried out for both peels to find out their potential in food applications. The moisture contents of prepared lime and mango peel powders were less than 10%. Both materials showed the higher carbohydrate (57.42% in lime peel powder and 64.19% in mango peel powder), more than 18% of crude fibre and considerable crude oil (6.87% in lime peel and 4.43% in mango peel) contents, explicating that both peels can be used in foods as sources for carbohydrate, fibre and oil. The study on physico-chemical and functional properties further showed that both peels could be a good source for carbohydrates including pectin and had the maturity stages of as good as that of resources being used for commercial pectin production. Fifteen experimental runs with different combinations of pH (1.3, 2.5 and 3.7), temperature (60, 75 and 90 °C) and time (45, 90 and 135 min) were employed according to the Box- Behnken design in the extraction of pectin. The yields of lime and mango peel pectins ranged from 8.1 to 21.9% and from 6.1 to 16.3% (dry basis) respectively. The empirical quadratic polynomial models developed for the effect of pH, temperature and time on yield and degree of esterification (DE) of both lime and mango peel pectins were significant ($p < 0.050$) and fitted to all experimental data with high co-efficient determination (> 95.00). Both models revealed that linear effects of pH, temperature and the interactive effects of pH, temperature and time showed significant impact ($p < 0.050$) on the yield and DE of lime and mango peel pectins. Optimized conditions of pH 1.7, 81.2 °C and 126 min yielded the maximum of 23.23% pectin from lime peel whereas optimized pH 3.38, 90 °C for 135 min yielded the highest of 17.1% pectin from mango peel. Lime peel pectin extracted under optimized conditions showed 857.0 ± 24.0 equivalent value, $8.3 \pm 0.4\%$ methoxyl content, $70.0 \pm 0.5\%$ DE, $77.0 \pm 2.1\%$ anhydro uronic acid content and 190 gel grade. Mango peel pectin possessed 2622 ± 35 equivalent value, $9.2 \pm 0.1\%$ methoxyl content, $88.5 \pm 0.3\%$ DE, $74.2 \pm 0.9\%$ anhydro uronic acid content and 190 gel grade. All these properties exerted that both lime and mango peel pectins were better than commercial pectin (INS 440i) and can be recommended for applications in food industry. The study further revealed that 69.51% fat in the commercial ice cream can be replaced with 0.3% pectin of either lime peel or mango peel pectin without causing any significant difference in its textural and melting properties and therefore, both lime and mango peel pectins can act as fat replacers in the water-oil- water emulsion well.

2021-MPhil

28. INVESTIGATION OF FRUIT PHENOLOGY AND PRE HARVEST FOLIAR TREATMENTS OF GROWTH REGULATORS ON FRUIT QUALITY AND

POSTHARVEST LIFE OF LIME (*CITRUS AURANTIFOLIA* SWINGLE)

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Abstract

Acid lime (*Citrus aurantifolia* Swingle) is a commercially viable cash generating high value fruit crop grown across the dry and intermediate zone of Sri Lanka. The price per kilogram of fresh lime dramatically fluctuates throughout the year as its marked seasonality of fruiting behavior and is the main obstacle for the expansion of lime industry. While the crop gained less attention and studies restricted to post-harvest treatments, in the present investigation fruit phenology of lime was evaluated by way of maturation curves developed in response to cumulative growing degree days (GDDs). Optimum harvest maturity was identified to obtain the best fruit quality and most extended postharvest life. Maturity indices were defined and thereby colour charts and sizing rings were developed to adopt under field conditions for easy identification of optimum harvest stage and to utilize in quality control. Furthermore, identification of the type and optimum dose of gibberellic acid (GA₃), brassinosteroids (BL) and salicylic acid (SA) as pre-harvest treatments either on hastening or delaying fruit maturity and improving quality and postharvest life under ambient storage were evaluated. Phenological phases of acid limes; cell division and differentiation, cell expansion, fruit maturation and senescence completed once, canopy accumulated 300 GDDs, 1400-1500 GDD, 2106.00- 2237.40 GDD and 2541.9- 2852.15 GDDs respectively that achieve 14- 28, 70-105, 133-147 and 171-179 DAFS (days after fruit set) respectively. Fruit SI, diameter, weight, peel thickness, per cent of juice content juice pH could be suggested as maturity indices for acid lime. Physiological maturity was attained once canopy accumulated 2106.00- 2237.40 GDD (147 DAFS; 5 month) and at the stage, mean fruit SI and diameter of 1.02 and 4.5-4.7 cm attained respectively along with minimum peel thickness (1.2-1.3 mm) and juice pH (2.2-2.4). Fruits at this stage had post-harvest life of 6-9 days under ambient storage (30-34 °C, 70-75% RH), could be recommended for fresh fruit market while fruits at 133 DAFS for storage/long distance marketing. Time taken to attain physiological maturity could be significantly ($p < 0.05$) advanced by foliar application of BRs and SA, and delayed by GA and improved fruit quality attributes and post-harvest, once applied at 14 and 28-42 DAFS. Pre-harvest treatment of GA with 25.0 and 37.5 mg/L could be recommended for late season harvesting that delay maturity nearly by 1 month and 1.5 month respectively with extended post-harvest life of 12-15 and 15-18 days respectively under ambient storage. Foliar application of 1.5 mg/L BR and 1.0 and 2.0 mM of SA could advance maturity by 2.5, 2.6 and 2.7 months respectively with post-harvest life of 12-15, 9-12 and 9-12 respectively. However, concerning the cost of plant growth regulators it could be recommended 1.0 mM SA at farmer level. These findings furnish to sort out suitable PGRs and doses, depending on market price and financial ability of the grower. As an alternative, grower can schedule split harvesting by treating different paddocks with different treatments.

29. ASSESSMENT OF AGRONOMIC FEASIBILITY OF *JATROPHA* UNDER MID COUNTRY WET ZONE CONDITIONS IN SRI LANKA

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Abstract

There are numerous *Jatropha curcas* L. accessions have been found within different agro-ecological zones in Sri Lanka. These accessions are having different characters in flowering, fruiting and total yielding in their territories over decades, with a pool of germplasm. It is most important to collect the country-wide germplasm and evaluate their performance in morphological plant growth characteristics. This is important as genetically improved trees will give better yields, associated with high quality oil and by products. Seventy two *Jatropha curcas* L. accessions collected in a previous study representing all areas in Sri Lanka were planted in a nursery at *Meewathura* research station of the University of Peradeniya. Among the 72 planted accessions only 32 accessions survived. In this study, 32 survived accessions were further assessed to select the most promising and the best performing accessions of *Jatropha curcas* L. under the conditions of Mid Country Wet Zone (WM3) of Sri Lanka. Hierarchical Clustering using Principal Component Analysis concluded that there were 3 clusters for T1 (fertilized) plant growth data, while there were 5 clusters of *Jatropha curcas* L. accessions for T2 (Unfertilized) plant growth data. Based on overall plant growth performance in T1, cluster 2 and 3 exhibited above average plant growth performance while cluster 1 exhibited below average plant growth performance. Based on overall plant growth performance in T2, cluster 2,3,4 and 5 exhibited above average plant growth performance while cluster 1 exhibited below average plant growth performance. Though *Jatropha curcas* L. is a rain fed crop, it requires specific amount of soil moisture content in the early stage of crop growth. Therefore, a study was carried out to evaluate crop water relationship in early five months of immature *Jatropha curcas* L. plants by using lysimeter analysis with water balance method under the conditions of WM3 of Sri Lanka. The lysimeter study concluded that, there were higher water losses in lysimeter pots having plants while the control (pot without a plant) show a slightly low water depletion pattern until 100 days after planting. When lysimeter pots were maintaining at a 60% management allowable soil moisture depletion, wilting characters appeared, and all the leaves fell within one week in five and half month old plants. At the 50% management allowable soil moisture depletion, all the leaves fell within three weeks in six months old plants.

30. DESIGN AND IMPLEMENTATION OF MATHEMATICALLY CONTROLLED TROUGH WITHERING TO OPTIMIZE ELECTRICAL ENERGY CONSUMPTION IN WITHERING OF TEA LEAVES

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Abstract

A control system was developed to optimize the electrical energy consumption in tea withering. The electrical energy saving was achieved by controlling the speed of the fan of the withering trough through a variable speed drive and controlling the hot and cold air delivering into the trough. The fan speed was determined based on the theoretical mass flow rate requirement of air, calculated by the mathematical model developed by Botheju et. al. (2010), for simulating the withering process. Further, the same mathematical model was used in calculating the thermodynamic properties of withering air and the moisture content of tea leaves in real time for determining the mass flow requirement of air. In this regard, the initial moisture content, leaf temperature as initial conditions and the real time temperature, relative humidity (RH) of air measured from sensors as boundary conditions, were provided to above mentioned mathematical model. Assuming the air conditions are not changing the model calculated, real time moisture contents were taken as the controller output, while predicting the moisture content in the next ten minutes of withering. In this study, standard linear curve of moisture contents versus time was taken as the set points of the control system. The difference between the moisture content of the withered leaves calculated by the model for an extrapolated time (ten minutes) interval and the standard withering curve were calculated. Depending on the calculated error, the software programme identifies required mass flowrate of air by achieving the final goal of electrical energy optimization. A single board computer, Raspberry Pi 3 model B was used to run the mathematical model and the software programme. The required hardware and software modifications were done to the experimental withering trough as necessary. Three trials were conducted in the experimental withering trough with measuring air flow rate of the inlet air by varying the frequency to 35 Hz, 40 Hz, 45 Hz and 50 Hz of the VSD. A linear relationship was observed between frequency of the VSD and the inlet air flow rate. Four polynomial equations were established with the relationship between pressure rise and the volume flow rate for a constant impeller speed (rpm). The developed control system was validated for energy saving by collecting withering data (temperature, humidity and moisture content of withering leaves with time) with the develop control system. Modifications were made to the software and the hardware as necessary. Finally, three test runs were conducted in detail for validating the model for energy saving with the control system. The energy consumption was considerably low and it was in the range of 36 to 39 kWh in the existed environmental condition with the control system while it was in the range of 55 to 67 kWh without the control system. The specific electricity consumption was 0.17 to 0.18 kWh/kg of made tea with the control system and it was 0.27 to 0.35 kWh/kg of made tea without control system. Therefore, the developed controlled system was capable of saving 39% electrical energy in trough withering with preserving the quality of made tea.

31. IDENTIFICATION OF PREVALENCE, PATHOGENS, AND RISK FACTORS OF SUB-CLINICAL MASTITIS AND DEVELOPMENT OF AN ENZYME BASED EARLY DETECTION METHOD FOR SUB-CLINICAL MASTITIS IN CROSSBRED COWS OF SRI LANKA

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Abstract

A study was carried out to investigate the prevalence of Sub Clinical Mastitis (SCM), isolate the pathogens and identify risk factors and to find out the effect of SCM on calving interval of a population of crossbred cows. Further, assessment were carried to find out the correlation among California mastitis test score (CMTS), somatic cell counts (SCC) and N-acetyl- β -D-glucosaminidase (NAGase) enzyme activity and the influence of SCM on the NAGase enzyme activity in milk and how to correlate with risk factors. A total of 283 crossbred (Jersey x Sahiwal) milking cows in Kurunegala district; 160 crossbred (Jersey and Friesian) in Kandy district and 162 crossbred (Sahiwal x Local and European x Local) in Eastern Province were used for this study. These cows were bred under routine breeding programmes on the recommendation of the government authorities, selected for high yield with more fat in the milk and with more tolerance adverse environmental temperature. When screening was based only district. The prevalence of SCM was 46% and it was 39% if based on both CMT and and Streptococcus spp. (7.2%, 5/70) in Kandy district. The age, parity, milk yield and breed showed positive correlations with SCM ($p < 0.05$). The prevalence of SCM was relatively high after the fifth parity. A positive correlation of increase in calving interval (more than 18 months) with SCM was observed. European cross was more likely to be positive for SCM than Local and Sahiwal crosses ($p < 0.02$). The prevalence of SCM on the dairy farms can be reduced by implementing more hygienic management practices and carrying out awareness programmes, highlighting the economic benefits of clean milk production. One of the best ways to encourage better practices is to reward farmers for clean milk production. The assay procedure for N- acetyl- β -D-glucosaminidase (NAGase) is considered to be the most reliable, simple, and rapid enzymatic method for estimating the severity of udder damage. The age and parity showed a positive correlation with enzyme activity and cross-bred animals did not show a significant correlation with SCC and enzyme activity but mean value of SCC and enzyme activity were higher when an animal showed more phenotypically related to European cross breeds cows than Sindhi or Sahiwal crosses. Correlation between mean enzyme activity and mean SCC is higher than correlation between CMTS and mean SCC. Therefore, detection of sub-clinical mastitis by enzyme assay has high accuracy than the CMTS method. This enzyme assay system is an alternative method to trace subclinical sub-clinical mastitis.

32. APPLICATION OF SUSTAINABLE LIVELIHOOD FRAMEWORK FOR WATER INTERVENTIONS TO IMPROVE LIVELIHOOD STATUS OF THE PADDY FARMERS IN BAYAWA TANK CASCADE IN SRI LANKA

R. Sudarshani

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Abstract

In Sri Lanka, rural sector consists of 77.4% of the population whose livelihoods mainly dependant on agriculture and related activities. Of the farmers, 70.5% are smallholders who own less than 2 ha and make a subsistence living, particularly paddy farmers. Water is a main limitation for improving agricultural production. Thus, efficient use of water through alternative water interventions for farming and other water related livelihoods is necessary to improve the livelihood status of the farmers. This study was conducted in six Grama Niladari (GN) divisions in the Bayawa Tanka Cascade area in Kurunegala District of North Western Province of Sri Lanka to identify and prioritise the water intervention needs and assess the present availability and demand for assets for the identified water interventions, and formulate strategies to bridge the gap. Questionnaire survey, Key Informant Interviews (KII), Focus Group Discussions (FGD) and field observations were conducted to identify and prioritise water intervention needs. Sustainable Livelihood Framework (SLF), which was often used by different agencies as their primarily analytical tool in order to identify the issues in their poverty alleviation programmes, has been adopted in this study as well. Indicators were developed through literature review, stakeholder consultation and expert consultation to assess the existing levels of capitals in the study area. In addition to the five capitals, climate shocks, seasonality and policy change are also considered in the analysis. Farming is the major water related livelihood in the study area. Farmers are engaged in home gardens with perennial crop cultivation (100%), brick making (2.1%) concrete pot and block making (0.6%), raring flower nurseries (0.8%), animal husbandry (3.0%),paddy milling after boiling (0.2%) and coir dust industry (0.2%) as water related livelihood strategies other than farming. Physical, social, human, natural and financial capitals were measured using 24, 12, 8, 7 and 11 indicators, respectively. In addition to water, financials capital and physical capital were found to be the most limiting capital during both *Yala* and *Maha* seasons. Though, water related livelihoods can be constrained by water availability, the study identified that financial and physical capitals can be limiting even under water available situations. Resource maps for each GN divisions were developed using PRA tools and Arc Map 10.2 to demarcate the locations of tanks, roads, schools, post office, agro-wells and communityhalls. Based on the existing situation, strategies were proposed to improve the livelihood status of the farmers. Rehabilitation of existing tanks, augmenting tanks by using the Deduru Oya irrigation channel, establishment of small scale industries within the villages, groundwater development, cultivation of other field crops, fertilizer policy intervention, adoption of micro irrigation systems, crop diversification, desiltation of tanks, development of infrastructure, rain water harvesting, improving credit facilities and effective agricultural extension and education are the strategies identified to improve the livelihood status of the farmers. Introduction of cash grant instead of fertilizer subsidy was seen as a threat to social capital as it will weaken the cohesiveness among Farmer Organisation (FO) members as fertilizer distribution among the members was one of the major responsibilities of FOs.

33. AERATED SOAKING IN COLD SOAKING OF PADDY AND TESTING OF A BIO-TOWER FOR TREATING LOW STRENGTH EFFLUENT

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Abstract

Parboiling of paddy is a hydrothermal treatment which involves soaking, steaming and drying prior to milling. The field survey revealed that cold water soaking is predominantly practiced by the small-scale millers while hot water soaking is practiced by the commercial scale millers. Duration of cold soaking varies from 48 to 72 hours for short grain paddy and 72 to 96 hours for medium and long grain (Nadu) paddy. Depending on the grain type and frequency of water change, it consumes 1.3 to 8 m³ of water per one tonne and soaked water is discharged to the environment as effluent without proper treatment. Therefore, this study was conducted to distinguish the effect of water recirculation and aeration on moisture absorption rate of paddy and effluent strength. Short-grain(BG 358/Samba) and Medium-grain(BG 300/Nadu) new and old paddy were used for this study and 100 mm PVC pipes of 1.3 m in height were used as the soaking tanks. There were three soaking treatments; submerged stagnant, submerged aerated recirculation and submerged unaerated recirculation. Water recirculation was done using 12V DC pumps and a shower was used for aeration. First 12 hours of submerged soaking was common for all. Thereafter, intermittent water recirculation was done for two units for next 24 h by operating pumps; 10 minutes on and 20 minutes off. Dissolved Oxygen (DO), pH, Electrical Conductivity (EC), Total Solid (TS) and Total Dissolved Solid (TDS) of soaking water were measured at two hour intervals. The moisture content of paddy was measured at six hour intervals. Final BOD and COD of three treatments were also measured. According to the results, the DO in paddy soaking water depleted to a minimum limit after 9 – 21 hours of stagnant soaking at the beginning. To match with the formal milling practice, initial overnight soaking for 12 h and aeration from the following morning with a cycle of 10 mins on/20 mins off is the most practical and acceptable aerated soaking process, immaterial of the age of paddy and type of grain. The aeration slightly increases the pH of the soaking water and that increases the soaking rate of grains while reducing the soaking time required for parboiling process. In addition, submerged aeration reduced the effluent strength to about one half. The aerated soaking reduces the effluent discharge to only once for soaking (1.3 m³/t (paddy)) and BOD loading rate to half (1.7 kg/t (paddy)) with respect to conventional cold water soaking. The cost of wastewater treatment is also about SLR 0.20/kg (rice) which is ten cents less than conventional soaking. The germination of paddy is not an issue when aeration is stopped for last three hours of soaking at commercial level. The milling yield and rice quality is slightly improved under aerated soaking at the industrial level and the consumer preference for cooked rice is also better than conventional soaking. The performance of the bio-tower could not be assessed due to inadequate preconditioning of the fixed bed material for microbial film formation. This happened due to intermittent and irregular supply of effluent to the bio-tower. Therefore, the bio-tower technology may have limited potential in small-scale rice mills due to irregular and intermittent processing schedule which limits the continuous supply of nutrients to the microbes in the fixed bed for their proliferation and survival.

Key words: Paddy soaking, Parboiling, Aeration, Dissolved Oxygen

2021- PhD

34. MICROPROPAGATION AND PRODUCTION OF AGAR WOOD FRAGRANCE COMPOUNDS BY PLANT CELL CULTURES OF *Gyrinops walla*

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Abstract

Gyrinops walla gaertn., an endemic species of Sri Lanka, is one of the tremendous source of world's most expensive agarwood. The evolving commercial importance and demand for agar oil in recent years has resulted in a great interest in fragrance compounds production, particularly in the possibility of altering the sustainable production by means of plant cell and tissue culture technology. The present study is aimed at developing an efficient in vitro rapid multiplication technique and to develop a technique for production of fragrance compounds of *G. walla* by plant cell and tissue culture techniques. Plant cell and tissue cultures were established routinely under sterile conditions from leaves, axillary buds and shoot tip explants and influence of culture media composition especially plant growth regulators and reduced nitrogen content was investigated on rapid multiplication, callus induction, proliferation and product synthesis of *G. walla*. Moreover, effect of different concentration of salicylic acid on product synthesis was also studied. Finger prints of calli, elicited calli, micropropagated plantlets and agarwood were developed and chemical markers were identified with the assistance of thin layer chromatography and gas chromatography-mass spectrometry. Efficient micropropagation protocol of *G. walla* was developed from axillary buds and shoot tip explants. At all the stages of micropropagation, culture media compositions were optimized. MS media supplemented with 1.0 mg/L BAP was the best for establishment of both shoot tips and axillary buds (80.0 % and 86.0 %, respectively). Regenerated axillary buds and shoot tips could be further multiplied (10.6 ± 0.93 shoot buds/regenerated shoot) and elongated (4.0 ± 0.26 cm) by transferring to MS medium supplemented with 40 g/L sucrose, 1.0 mg/L BAP and 0.1 mg/L IBA while 50.0 % multiplied shoots rooted by transferring to $\frac{1}{2}$ MS semi-solid medium supplemented with 0.1 mg/L NAA and 40 g/L of 67.0 % by transferring to $\frac{1}{2}$ MS liquid medium supplemented with 0.5 mg/L IBA. Highest percentage (89.0 %) of shoots were rooted in the ex vitro condition, when the shoots were dipped in 1000 ppm of IBA for 30 minutes. 80.0 % of rooted plantlets were successfully survived during acclimatization in the media containing sterilized sand, top soil and compost mixture at 1:1:1 ratio. Callus culture were developed from leaf explants of *G. walla*, cultured on basal MS medium supplemented with different concentrations and combinations of plant growth regulators. MS media added with cytokinin or auxin alone have no effect on callus initiation/proliferation and 2, 4-D at low concentration in combination with BAP and/or kinetin was essential to enhance the callus initiation, cell proliferation, as well as product synthesis. Callus induction was increased with the decrease in NH_4NO_3 concentration. MS medium with half NH_4NO_3 level (825 mg/L) containing 1.0 mg/L BAP and 0.1 mg/L 2, 4-D was found to be the most efficient culture medium to obtain desirable quality callus mass with highest callus induction percentage (100 %), specific growth rate (374.3 mg/week) with fastest cell doubling (1.8 weeks). Moreover, growth of salicylic acid added calli showed inverse relation with concentration and showed close relationship with product synthesis. In the TLC fingerprints, similar spots were identified among the ethyl acetate extracts of best callus lines (MS medium supplemented with 1.0 mg/L BAP, 0.5 mg/L kinetin, 0.1 mg/L 2, 4-D and modified MS media with half level of NH_4NO_3 (825 mg/L) added with mg/L BAP, 0.1 mg/L 2, 4-D), stem, bark, tissue culture plantlets and agarwood at the retention factors (Rf) of 0.60, 0.66, 0.78 and 0.87, which served as a reference for GC-MS study. Calli treated with 1 mM SA, harvested at 12 weeks after inoculation was found to be the best in product synthesis from comparing the TLC profiles. Moreover, growth of salicylic acid (SA) added calli showed inverse relation with concentration. Agarospirol, aristolene and eicosane were the aromatic constituents found in agarwood. α -caryophyllene was one of the key fragrance

compounds identified in calli of *G. walla*. Moreover eicosane and squalene were also identified. The present study successfully established a protocol for rapid multiplication and also paves the way for the production of agarwood resinous fragrance compounds through cell culture techniques of *G. walla*.

Key words: *Gyrinops walla*, rapid multiplication, plant cell culture, elicitation, fragrance compound

2022- MPhil

35. UNDERSTANDING THE SYSTEM PRODUCTIVITY DURING THE TRANSITION PERIOD FROM CONVENTIONAL TO ORGANIC NUTRIENT MANAGEMENT SYSTEMS UNDER DIVERSE RICE-BASED CROP ROTATIONS IN THE DRY ZONE (DL1B) OF SRI LANKA

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Abstract

Sri Lankan agricultural sector also revised to mineral fertilizer application with the adaptation of the green revolution. However, due to the adverse effects of long-term use of mineral fertilizers, its focus is to shift from mineral to alternative fertilizers. Among the numerous alternative fertilizer applications, organic and integrated nutrient management are the main topics of discussion. However, the alternative systems cannot be sustained without integrated strategic planning and, the designing of cropping systems during the transition period. Weed is the most competitive biotic factor that in contrast to the achieve optimistic final crop yield, especially during the transition period. Crop rotation is an effective remedy for nutrient and weed management. However, there is a lack of research conducted under this broad-spectrum approach to rice-based systems during the transition period. So, this research fundamentally targets to identify the integrated impact of crop rotation and different nutrient management systems on rice-based cropping systems in two years of the transition period in a dry zone of Sri Lanka. The field experiment was conducted at Puliyankulama in the research unit of the Faculty of Agriculture, the Rajarata University of Sri Lanka over two years, encompassing two *Maha* (wet) seasons (2018/19 and 2019/20) and two *Yala* (dry) seasons (2019 and 2020). This study was conducted during the transitional period with conventional (CONV), integrated (INT), and organic (ORG) nutrient management under four types of crop diversification intensities in a dry zone region of Sri Lanka. Mono-cropped rice (LOW) and a rice-maize rotation (HIGH) were the starting point. After 1 year, the intensity of diversification was increased by adding interseason sunn hemp (rice-sunn hemp-rice; MEDIUM and rice-sunn hemp-maize; VERY HIGH). The split block design was used with nutrient management as the main plot factor and crop rotation intensities as a sub-plot factor. Three replicates were used in all seasons of the study. The ORG nutrient management system reported crop N improvement, while CONV and INT had a negative impact on both crops. Similarly, crop growth and physiology of the rice crop also positively responded to the ORG system in the 2nd cycle. Despite ORG LOW rotation being comprised of high productivity during the 1st cycle, ORG HIGH rotation achieved higher productivity during the 2nd cycle. The final grain yield of all LOW rotation nutrient management systems was stable with both cycles, but the final yield of INT and ORG systems increased with HIGH rotation of the 2nd cycle. VERY HIGH rotation with three nutrient management systems resulted in similar productivity during 2nd cycle. Crop rotation at INT reported lower weed density and biomass at both cycles. After five seasons, yields were stabilized and ORG and INT nutrient management also delivered a yield of 4.1-4.2 Mg ha⁻¹season⁻¹. Annual yields were 20% more in high rotation intensities than low. Weeds were suppressed by all systems, where intensified rotations reduced weed densities to a minimum. The initial decline in yield can be reversed by the substitution of inputs and selected crop rotations when converting to a conventional alternative. The reduction of mineral fertilizers by half and compensation with organic fertilizers was positive for all crop rotations with the expected yield level for short-term and long-term practice. And the anticipated yield can be obtained after four seasons of organic practice, despite the expected yield level was low at the initial stage. The organic system showed a positive response with production development which was parallel to the conventional with high crop diversification. Weed density and biomass were reduced with long-term high crop rotation diversification with all different nutrient managements. Therefore, high crop rotation intensity is the most suitable and possible method of weed control by an organic farming method with the improvement of productivity within two years of the transition period.

36. EVALUATION OF MILK COAGULATION PROPERTIES AND QUALITY OF SET-YOGHURT MANUFACTURED FROM INDIGENOUS AND EXOTIC CATTLE BREEDS/TYPES IN SRI LANKA

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Abstract

In Sri Lanka, non-descriptive indigenous cattle types which are reared under the low-input extensive management system are scattered in some parts of the island. Despite poor milk yield, exploring the potential of indigenous cow milk for the development of dairy products, which potentially deliver advanced nutritional and sensorial properties could support the conservation of these valuable genetic resources through better utilization. This research study aimed to assess, the milk compositional traits between two indigenous cattle types, Thamankaduwa White (TW) and Lankan cattle (LC) compared to two exotic cattle breeds, Friesian and Jersey. Further, set-yoghurts made from these types and breeds of cattle were compared with special reference to microbiological (probiotic viability), textural and sensory properties. Milk coagulation property (MCP) variations among these cattle breeds/types were also assessed. Milk coagulation property traits including rennet coagulation time (RCT), curd firmness and coagulum yield were measured. The protein profile of each breed/type was analysed using capillary zone electrophoresis. Cattle breed/type evident an effect on milk composition in relation to milk fat and total solids content. Friesian milk had the lowest ($p < 0.05$) fat content while TW and LC milk showed significantly higher ($p < 0.05$) total solid contents than those of Friesian and Jersey. Set-yoghurt made from indigenous cattle types showed the highest ($p < 0.05$) viability for yoghurt starter bacteria and probiotic bacteria. Set-yoghurts made from TW milk had the highest ($p < 0.05$) overall sensory acceptance and textural properties including higher ($p < 0.05$) firmness, cohesiveness and apparent viscosity. According to MCP analysis, significantly lower ($p < 0.05$) RCT was observed in two indigenous cattle types than that in two exotic cattle breeds. Friesian and TW milk had the longest and the shortest ($p < 0.05$) RCT respectively. There were no significant differences ($p > 0.05$) in firmness among the set-yoghurt of four breeds/types. The highest ($p < 0.05$) coagulum yield was recorded for TW milk followed by LC, Jersey and Friesian in both rennet and LAB coagulation. As revealed by the protein profiles, κ -casein concentration was significantly high in TW milk compared to the milk from other three breeds/types. None of the other milk protein genetic variants showed significant differences among the four breeds/types. Principal component analysis (PCA) revealed that coagulum yield and meltability of indigenous cattle milk had moderate influence from β -casein A1, β -casein B, α -lactoglobulin and κ -casein proteins. Thus, milk from indigenous cattle types is likely to be better suitable in producing set-yoghurts with superior probiotic viability, textural and sensory properties, compared to milk from exotic breeds. Overall results indicated that the superior MCP properties of TW milk, emphasizing the value of native breeds which could be utilized in the development of unique dairy products while supporting the conservation effort of the native cattle gene pool.

37. ESSAYS ON THE ECONOMICS OF THE COCONUT SECTOR IN SRI LANKA

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Abstract

Coconut, (*Cocos nucifera* L.), one of the three traditional export crops of Sri Lanka plays an important role in sustaining the national economy and food security. Amidst all the policy efforts, slow growth and low returns of the coconut industry have been at the forefront of debate and controversy over the decades. Therefore, this study aims to assess the present situation in the Sri Lankan coconut industry from different economic perspectives including both short-run and long-run behaviour of producers, consumers and the coconut market while assessing the productivity growth of the sector. To assess the short-run static equilibrium relationships in the Sri Lankan coconut market, the Partial Equilibrium Model (PEM) adopted by Samarajeewa (2002) was re-estimated using the Seemingly Unrelated Regression (SUR) method. Annual data for the period 1956-2017 were used for the analysis. The results revealed that estimations are consistent with previous studies except for the income variable in demand equations for both fresh and oil markets where only the latter is statistically significant with a negative coefficient indicating that oil has become an inferior good. Both the own price elasticity of supply and demand for fresh nut and oil are statistically significant with comparatively lower magnitudes whereas it is significant and higher in the DC market. The magnitudes of the supply and demand elasticities in the coconut market have changed over the past decade and implications of those changes are further observed in the changes of directions of supply and demand relationships. To assess the long-run dynamic supply relationships in the coconut market, the cointegration approach was employed. Regional variations in the domestic coconut production in Sri Lanka, India (represented by the state of Kerala) and the Philippines were captured by applying a Vector Error Correction Model (VECM). National aggregate time series data for the period 1970-2016 were used in the analysis. The empirical results show that unique long-run equilibrium relationships exist among coconut production, the coconut price, and the climate variable in three individual markets and the panel estimation. The speed of adjustment towards long-run equilibrium has the expected sign and it is significant in all four estimations with a -0.14 value in the panel estimation. Thus, 14% of adjustment is completed each year and it will take nearly 7.14 years to achieve the long-run equilibrium. The regional disparities are revealed by the short-run dynamics throughout the analysis. Both short-and long-run price elasticity of coconut supply is inelastic amidst its significance, suggesting that any pricing policy requires a comparatively long lead time for it to become effective in accelerating coconut production. The estimated panel VECM can be further developed and validated to be used as a tool to analyze the regional deviances for assisting the policymakers in making comprehensive strategies to ensure the industry's long-term sustainability. To identify the sources of productivity growth of the Sri Lankan coconut sector and to decompose the measured growth in Total Factor Productivity (TFP) into technological change and returns to scale, a cost function approach was used. The national aggregate cost of production data over the period 1961- 2016 were used in the analysis. According to the results, the TFP was found to have grown at 0.083% per annum. Furthermore, results revealed that coconut cultivation was characterized by a high labour share and low material and capital share. Technological progress comprises the majority of TFP growth accounting for 78% while the scale economies contributed 22%. The contribution of technical progress is greater towards the end of the considered period while diseconomies of scale is operating throughout the period. Based on this, we recommend that the focus of the coconut sector development should be on technological interventions rather than the consolidation of coconut land.

38. DESIGN, FABRICATION, AND PERFORMANCE EVALUATION OF A ROTARY DRUM ABRASION PEELING MACHINE FOR SPHEROIDAL FRUITS AND VEGETABLES

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Abstract

Fruits and vegetables peeling is a key unit operation commonly performed at the early stages of food processing lines. There are four common methods practised in fruits and vegetables peeling: manual, mechanical, thermal, and chemical. The appropriate method of peeling is relied on the nature of the peel, purpose of peeling and the product. Moreover, mechanical, thermal, and chemical peeling methods are not preferred by small-scale Sri Lankan food processors due to high initial cost, high peeling losses, less peeling efficiency, and conformity of a machine to a single purpose. However, the mechanical method is the most preferable despite absence of highly effective peelers for Micro, Small and Medium Enterprises (MSMEs) to minimize their cost of production. Naturally, most of the fruits and vegetables used for processing are spheroidal in shape. Therefore, this research was aimed to develop an appropriate, continuous type, rotary abrasion peeling machine for spheroidal soft and thin skin fruits and vegetables. In addition, especial attention was paid to satisfy the needs of the MSMEs in Sri Lankan food industry. After a critical review of literature and a series of primary tests, comprehensive design calculations were performed. The newly designed rotary abrasion peeling machine consists of a power source, frame, and separate mechanisms for feeding, abrasion peeling, washing, and collecting foods and power transmission, which are facilitated to peel and clean the raw foods, achieve the required power, and machine control during the mechanical peeling. After fabricating the machine, series of performance tests were carried out using potato (*Granola* variety) and Ambarella (Large and Miniature fruit types) and required modifications were also done. In performance evaluation, appropriate horizontal drum angle for mechanical peeling of potato and Ambarella were investigated. Subsequently, in comparative performance evaluation, machine peeling was compared against common manual peeling with knife. According to the results, the best suited horizontal drum angle for peeling potato and Ambarella were found as 10°. The actual peeling capacity of potato in machine peeling was significantly higher (15 times) than manual peeling ($p < 0.05$), the peeling efficiency of manual and mechanical were found to be 100% and 87.57%±0.98, respectively. Moreover, the new peeling machine showed significantly higher actual peeling capacity for mechanical peeling of Ambarella in comparison to knife peeling (22-fold higher for both types) ($p < 0.05$). However, the peeling efficiencies of Ambarella were significantly lower in machine peeling method with respect to manual knife peeling ($p < 0.05$). Furthermore, a minimum material loss of less than 5% achieved for both potato and Ambarella in machine peeling which is a great achievement. The costs of machine peeling per kilogram of potato and Ambarella were Rs. 2.13 and Rs. 2.08, respectively whereas manual peeling Rs. 30 for potatoes and Rs. 40 for Ambarella. The labour requirement for machine peeling of potato and Ambarella are 15 and 19 times less than manual peeling. Based on the machine capacity, it is appropriate for MSMEs. However, further improvements are needed to enhance the Ambarella peeling efficiency and machine should be tested for other spheroidal shape fruits and vegetables as well.

2022-PhD

39. DEVELOPMENT OF FERTILISER RECOMMENDATION FOR MAJOR SUGARCANE-GROWING ALFISOLS IN SEVANAGALA, SRI LANKA WITH REFERENCE TO SOIL PHOSPHORUS AND POTASSIUM AVAILABILITY

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Abstract

The need of precise and verified chemical fertiliser recommendations to increase yield and quality of cane in a sustainable manner was an urgent requirement of the sugar sector in Sri Lanka. Therefore, *Sevanagala* sugarcane-growing Alfisols representing two irrigation regimes, namely irrigated and rain-fed, were selected as a model, where detailed soil properties were also studied. A comprehensive systematic soil survey was carried out to determine macro- and micronutrient status at *Sevanagala* to investigate the spatial variability. The results revealed that a considerable amount of P and K had been accumulated in soil over the years, which could be favourable at times, and also unfavourable for plant growth. Considering the minima of N, P and K levels in certain locations, suitable adjustments are necessary paying attention to site-specific approaches in recommendations. Soils with low available micro-nutrient (Mn, Zn and Cu) concentrations were identified in the study area, though visual deficiency symptoms were not observed. Though not a nutrient, the results of exchangeable Na indicate that it is important to improve drainage in LHG soils under the rain-fed conditions or else it would be unfavourable for sugarcane cultivation in the near future owing to potential alkalinity. The soil survey concluded that there are eight soil categories with 4 each representing LHG and RBE of entire *Sevanagala* region. Based on soil threshold levels of a previous study, suitable P and K concentrations were ascertained as 20 mg kg⁻¹ and 150 mg kg⁻¹ respectively. Thereby, soils of *Sevanagala* sugarcane-growing area was divided into four main P and K concentration categories laid down as, < 20 mg kg⁻¹ P and < 150 mg kg⁻¹ K (Low P Low K), < 20 mg kg⁻¹ P and > 150 mg kg⁻¹ K (Low P High K), > 20 mg kg⁻¹ P and < 150 mg kg⁻¹ K (High P Low K) and > 20 mg kg⁻¹ P and > 150 mg kg⁻¹ K (High P High K). Investigations on Quantity/Intensity relationships of soil potassium were carried out to arrive at a classification key. Based on the outcome, *Sevanagala* sugarcane-growing soils could be characterised into two main groups as high K buffering, high labile K (irrigated soils) and low K buffering, low labile K soils (rain-fed soils). The former possessed lower K specific sites and the latter higher K specific sites. The adsorption/desorption to concentration graphs on soil P indicated that soil has a high P adsorption capacity indicating the high potential to adsorb phosphate ions. Adsorption maxima of P in these Alfisols are higher and it indicated possibility of P deficiency as a main agronomic limitation. Based on the soil threshold levels for P and K, and subsequently identified soil groups were used to establish a pot experiment under controlled conditions with four P and K concentration combinations in both LHG and RBE soils packed in 70 L pots. Each pot was planted with one bud and maintained the crop for 12 months until harvest. Furthermore, field trials were established at different locations representing *Sevanagala* sugarcane-growing soils. The pot experiment results were used to explain the field trial derived results as well. The site-specific fertiliser recommendations were established based on the irrigation regimes, soil K buffering capacity and soil P and K concentration categories. It was revealed that the optimum P and K fertiliser application rates for 'Low P Low K' category was 20 kg ha⁻¹ and 0 kg ha⁻¹ respectively. The optimum P and K fertiliser rates for 'Low P High K' were 0 kg ha⁻¹ and 150 kg ha⁻¹ respectively. The optimum P and K fertiliser rates for 'High P Low K' category were 40 kg ha⁻¹ and 300 kg ha⁻¹ respectively. The optimum P and K fertiliser rates for 'High P High K' category were 20 kg ha⁻¹ and 150 kg ha⁻¹ respectively. One of the main phenomenon recognized in this study was the contrasting difference of clay contents among irrigated and rain-fed regimes. The irrigated regime showed significantly higher clay contents than that of the rain-fed regime. It is proposed that the present general chemical fertiliser recommendation of P: K (20 and 150 kg ha⁻¹ respectively) be continued in locations where site-specific will not be adopted.

Future studies should be directed to identify the contribution of clay and organic matter on nutrient retention and to identify means of improving their capacities towards an integrated nutrient management system in view of reducing synthetic fertiliser and increasing the overall fertility of soils. Other future studies necessary were presented at the end of the conclusions section.

40. RHIZOBACTERIA INDUCED SYSTEMIC RESISTANCE IN *Carica papaya* L. var. RED LADY FOR MANAGEMENT OF PAPAYA RINGSPOT VIRUS DISEASE IN SRI LANKA

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Abstract

Papaya (*Carica papaya* L.) is a fruit crop with high socio-economic value and widely cultivated in tropical and subtropical countries. Several viruses have been reported infecting papaya and among them *Papaya ringspot virus* is a serious biotic threat as it causes papaya ringspot virus disease (PRSVD). As no effective management strategies are available for virus diseases, current trend has been focused on induced systemic resistance (ISR) in plants with rhizobacteria. Nevertheless, no research attempts have been reported on the use of rhizobacteria to induce systemic resistance against PRSVD in Sri Lanka. This study was planned to determine the potential use of rhizobacteria dwelling in papaya rhizosphere to manage PRSVD in papaya. Rhizosphere soil of healthy papaya plants were collected from papaya cultivations. Bacteria were isolated and identified by morphological, physiological, biochemical, and molecular methods. Identified bacterial isolates were inoculated by two methods, namely seed bacterization and soil drench. Effective rhizobacteria were screened by a pot experiment. Field efficacy of effective isolates was determined by application of individual bacterial isolates and mixtures of selected bacterial isolates. Induction of defense enzymes in leaf tissues due to inoculation of rhizobacteria was quantified by standard spectrophotometric analyses. The confirmation of expression of defense related genes was done by molecular methods (RT-PCR). Further, ability of survival of the *Pseudomonas* spp. on several potting media was tested. Twenty fluorescent *Pseudomonas* spp. and four *Bacillus* spp. isolates were identified from the papaya rhizosphere. Those isolates were confirmed as *Pseudomonas* spp., *Pseudomonas fluorescens*, *Pseudomonas taiwanensis*, *Pseudomonas putida*, *Pseudomonas aeruginosa* and *Bacillus cereus* by DNA sequencing. At the initial screening, five *Pseudomonas* isolates (i.e. 1, 46, 53, 74, and 78) and one *Bacillus* isolate (B1) were selected as better performing isolates in terms of the plant growth and reduction of severity of foliage symptoms of PRSVD. Field experiments conducted revealed the ability to reduce PRSVD symptom severity on foliage and fruits when the selected rhizobacterial isolates were applied as single isolates by both application methods. When rhizobacteria were applied as a *Pseudomonas* and *Bacillus* isolates mixture by seed bacterization, a significant reduction of disease severity of the foliage was observed. Fruit yield was significantly higher in plants treated with mixtures of rhizobacteria as a soil drench. Significantly lower area under disease progress curve (AUDPC) was observed when rhizobacteria mixtures were applied by both methods. Therefore, use of combined mixtures of *Pseudomonas* and *Bacillus* isolates and/or mixtures of *Pseudomonas* or *Bacillus* isolates can be considered as a promising option under field conditions for suppression of PRSVD and to achieve some other additional advantages such as reduction of symptom severity on fruits and to obtain a better yield. Application of some rhizobacterial isolates as single isolates under pot experimental condition resulted in higher peroxidase (POX) activity by seed bacterization and soil drench. A higher beta-1,3-glucanase and PAL activity were observed in leaf tissues of the plants treated by soil drench method. Moreover, when plants were applied with mixtures of *Pseudomonas* isolates by seed bacterization or soil drench method or the combination of the two application methods, the activity levels of POX, beta-1,3-glucanase and PAL enzymes in leaf tissues were increased. Further, RT-PCR confirmed the expression of POX and PAL genes when all types of rhizobacterial mixtures were applied by seed bacterization. Compost and cow dung (1:1) mixture when used as potting medium showed the best survival of *Pseudomonas* isolate.

Findings of the research revealed the possibility of using single isolates or mixtures of *Pseudomonas* and *Bacillus* isolates which were isolated from papaya rhizosphere have the potential of reducing PRSVD severity. Therefore, the identified effective rhizobacteria isolates can be used as a biological component in integrated management of PRSVD.

**41. EVALUATION OF SELECTED SRI LANKAN RICE VARIETIES
FOR PHOSPHORUS (P) UPTAKE AND USE-EFFICIENCY,
IDENTIFICATION OF THE PRESENCE OF PUP1 QTL AND
DEVELOPMENT OF P DEFICIENCY TOLERANT RICE
VARIETIES THROUGH DNA MARKER ASSISTED SELECTION**

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Abstract

Rice (*Oryza sativa* L.) is of immense importance when reaching food security of Sri Lankans. Utilizing low-fertile rice fields is one of the best alternatives for increasing rice production. Therefore, rice varieties having comparatively higher productivity in low-fertile soils and their adaptive mechanisms need to be identified. Phosphorus (P) is one of the major nutrients, limiting the yield in low-fertile rice fields. Development of a methodology to identify P deficiency tolerant varieties and their adaptive mechanisms under P deficiency condition is important when improving P use efficiency in rice. Phosphorous Starvation Tolerance 1 (PSTOL1) gene in the P uptake 1 (Pup 1) QTL has been identified as the major gene conferring P uptake and utilization efficiency in rice. Therefore, the identification of rice varieties having PSTOL1 gene will step up the precise P deficiency (PD) tolerance in rice breeding. Moreover, evaluation of the expression of PSTOL1 gene in different varieties under local environmental conditions will provide an understanding of the differential gene expression of varieties. The present study focused on the improvement of PD tolerance in rice breeding with the objective of increasing productivity of rice in low-P areas. A field experiment was conducted to test 44 popular local rice varieties in fertile and low-fertile (P limited) sites for five consecutive seasons to identify the best suited varieties for low-P conditions. Best varieties were identified based on growth and tissue nutrient analyses. A hydroponic screening methodology was developed for screening of rice varieties at low-P availability. For this, six P levels, 5, 10, 20, 50, 100 and 250 μM were used. Out of them, 10 μM and 50 μM P concentrations were identified for testing rice varieties at P deprived and optimum conditions, respectively. In the following experiment, 48 rice varieties were screened at 10 and 50 μM P levels in hydroponic condition. Based on the results, tested rice varieties were categorized as P deficiency tolerant or susceptible. The same rice varieties were assessed for the presence of PSTOL1 gene by PCR amplification of K46-1 dominant marker. Presence of full PSTOL1 gene was confirmed in selected rice varieties using five primer pairs designed. Relative expression of PSTOL1 gene was assessed in eight selected rice varieties at 10 and 50 μM P levels using semi-quantitative PCR with gene α -tubulin as housekeeping control. Interestingly, around 80% of Sri Lankan rice varieties showed the presence of PSTOL1 gene. However, there was no clear relationship between the level of P efficiency of selected rice varieties and the presence /absence of PSTOL1 gene. Further, there was no relationship between P deficiency tolerance and the expression of PSTOL1 gene. Therefore, the presence of PSTOL1 gene and/or its expression are not directly linked to P deficiency tolerance of Sri Lankan rice varieties. A breeding program for high yield and PD tolerance was initiated using Bg300, Bg94- 1, H4 and At353 as PD tolerant parents. Single seed descent (SSD) breeding method was used for the generation advancement to develop recombinant inbred line (RIL). Multiple plant traits were used for selecting PD tolerant RILs. Presence of PSTOL1 gene in RILs was confirmed by marker-assisted selection and related by agronomic evaluation. Finally, ten promising PD tolerant and high yielding rice lines were developed with accepted agronomic traits. This study would be a platform for advancing rice breeding programs for efficient soil P usage

42. SPECIES REPLACEMENT OF WHITE-EYES (PASSERIFORMES: ZOSTEROPIDAE) ALONG AN ALTITUDINAL GRADIENT

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Abstract

Species, except humans and their commensals, generally have a restricted distribution where they are replaced by a closely related species at the edge of their range. The overall aim of this study was to investigate species replacement of the Oriental white-eye (*Zosterops palpebrosus*) (OWE) and Sri Lanka white-eye (*Z. ceylonensis*) (SLWE) in Sri Lanka. The first objective was to document the densities of the two species in sympatry and allopatry. There was a marked decline in the density of the OWE from the end of its allopatric zone to sympatric zone, while SLWE densities did not show a change between allopatric and sympatric zones. Habitat differences in the sympatric and allopatric zones were investigated in detail under the second objective. It was evident that there was a clear change in the vegetation with increasing elevation, where the canopy height and tree density decrease, and the foliage height diversity increase, with elevation. The replacement of the OWE by the SLWE may occur partly due to the changes in vegetation. The third objective was identified to document differences in morphological characters such as bill length, bill width, tarsus length, and wing length, in allopatric and sympatric zones. The findings revealed that the sympatric population of the SLWE has evolved differences in bill length and width, enabling it to be ecologically isolated from the smaller OWE, thereby facilitating coexistence. The larger bill of the SLWE in sympatry enables it to be more successful in obtaining food compared to OWE. This is also reflected in the finding that the density of the OWE decreases from the lower to the upper end of the sympatric zone, facilitating a gradual replacement of the OWE in the upper elevations. The fourth objective targeted the niche breadth and overlap of the two species in allopatry and sympatry to study how they partitioned the use of habitat in sympatry. The results confirmed that there was a decrease in the niche breadth of the OWE in sympatry, demonstrating some competitive pressure from the larger SLWE. The two species showed a marked difference in partitioning the resources. Overall, the replacement of the Oriental white-eye at higher elevations with the slightly larger Sri Lanka white-eye may be said to have taken place due to a combination of reasons outlined above, *viz.* differences in densities, habitat differences, morphological characteristics, and changes in niche breadth and overlap.

**43. IMPACT ASSESSMENT OF THE DIFFERENT BARK CONSUMPTION RATES
ASSOCIATED WITH ADDITIONAL DAYS OF LATEX HARVESTING ON
GROWTH, YIELD AND ECONOMIC IMPLICATIONS OF RUBBER
(*Hevea brasiliensis* Muell. Arg) PLANTATIONS**

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Abstract

Latex extraction from a rubber tree should be done at a frequency which ensures a higher rubber yield over its entire economic life span. The recommended tapping frequency is once-in-two days (d2), while low-frequency tapping is at once-in-three days (d3) with yield stimulation. However, rubber growers deviate from above recommendations by tapping at higher frequencies to recover the loss of tapping days due to rain (i.e. 'recovery tapping') or tapping daily during rain free periods. Therefore, the principal objective of this study was to determine impacts of high-intensity tapping (HIT) on the (1) rubber yield, (2) tree girth increment, (3) bark anatomy, (4) selected physiological properties of latex and (5) economy of a rubber plantation. As genetic variation among rubber clones could determine the magnitude of these impacts, assessment of clonal variation in the effects of HIT and thereby identify clones amenable to HIT was secondary objective. An on-station experiment was conducted during 2013-2017 period in a field planted in 1999 at Kuruwita sub-station of the Rubber Research Institute. Treatment structure was a two-factor factorial in split-plot design with five tapping systems and four clones (RRIC100, RRIC102, RRIC121 and RRIC133) as main-plot and sub-plot factors respectively. The five treatments (T), which represented different tapping intensities and bark consumption rates, were: T1-S/2 d2 without recovery tappings (RT); T2-S/2 d2 with recommended three RTs per month; T3-S/2 d2 with 5 RTs per month; T4-S/2 d3 plus stimulation with 2.5% Ethephon; T5- S/2 d1 (daily tapping). Treatments were applied in 2013 and measurements were taken over three years from 2014 to 2016. Low-frequency tapping (LFT) with yield stimulation produced a greater latex volume (LV) than others. As time progressed, HIT in T3 and T5 decreased LV below that obtained with T1 and T2. Significant clonal variation was observed in response of LV to LFT with stimulation and daily tapping, where RRIC121 and RRIC133 showed superior performance than RRIC100 and RRIC102. Dry rubber content (DRC) decreased (with HIT in T3 and T5 in all clones. RRIC121 had higher DRC ($P < 0.05$) than other clones across all treatments. Rubber yield per tree per tapping (YTT) decreased ($P < 0.05$) with HIT in all clones, but increased with LFT. Clones RRIC121 and RRIC133 had greater YTT than RRIC100 and RRIC102 across all treatments and also showed a greater response to LFT with stimulation. During the three years of this study, HIT did not show a clear ($P > 0.05$) adverse effect on rubber yield per tree per annum (YTA), because reduced YTT was compensated by increased tapping frequency. However, a decreasing trend in YTA was detected in T3 in the third year. Intake per tapper (IPT) was greater with LFT, while HIT did not show a clear effect. Bark consumption and incidence of tapping panel dryness (TPD) were greater ($P < 0.05$) with HIT, but lower with LFT. Tree girth increment and bark regeneration were not affected by recovery tapping (T2 and T3) during the first three years. But, daily tapping (T5) and stimulation (T4) decreased girth increment in lower-yielding clones (RRIC100, RRIC102), while higher-yielding clones (RRIC121, RRIC133) were not affected ($P > 0.05$). Number of latex vessel rings (LVRs) in the untapped virgin bark was higher in higher yielding clones and *vice versa*. In higher-yielding clones, HIT reduced the number of LVRs in the renewed bark. High-intensity tapping (T2, T3 and T5) decreased phloem turgor pressure, thus contributing to reduce YTT by reducing LV. Stimulation plus LFT and daily tapping increased latex sucrose content (LSC) whereas recovery tapping did not. Net cash flow declined in HIT after two years due to reduced IPT and increased TPD, while economic life span was reduced due to faster consumption of tapping panels. More importantly, the Benefit Cost Ratio (BCR) was higher in LFT than HIT during the period of study indicating high return for the investment. Based on these findings,

it is concluded that HIT, either through recovery tappings or daily tapping, brings about adverse medium- and long-term impacts on productivity and economic life span of a rubber plantation. These impacts would occur earlier in lower-yielding clones than in higher-yielding clones.

44. SCREENING OF RICE VARIETIES FOR LOW NITROGEN CONDITIONS AND DEVELOPMENT OF A SUITABLE NUTRIENT MANAGEMENT PACKAGE TO ENHANCE NITROGEN UPTAKE OF SELECTED RICE VARIETIES FOR LOW INPUT CONDITIONS AND ORGANIC FARMING

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Increase of nitrogen (N) fertilizer use efficiency is an important aspect to maintain soil fertility and environmental quality. Nitrogen Use Efficiency (NUE) of wetland rice cropping systems is less than 30% and it is known to be a key factor of low yields. The main objective of the study was to increase the NUE of selected rice varieties, which performed better under low input conditions by formulating appropriate nutrient packages along with inoculants of N fixing bacteria. Specific objectives were (i) to screen the best performing traditional and improved rice varieties under low input conditions especially under organic farming, (ii) to assess the population densities of rhizosphere bacteria of selected rice varieties grown under different nutrient input conditions and isolate N fixing bacteria associated with selected rice varieties and (iii) to formulate a suitable nutrient package including effective N fixing bacterial inoculants along with solid and liquid organic nutrient sources to improve N uptake and yield of selected rice varieties identified as suitable for low input conditions and organic farming. The rice varieties with high NUE were screened among fifteen popular traditional and improved rice varieties under three nutrient management systems as no fertilizer inputs (NF), organic inputs (OF) and conventional fertilizers (CF) at Rice Research and Development Institute (RRDI), Bathalagoda and Sustainable Agriculture Research and Development Centre (SARDC), Makandura in Kurunegala district during 2012 / 2013 *Maha*, 2013 *Yala* and 2014 *Yala* seasons. Variety screening was performed based on growth parameters, N uptake and yield of rice varieties grown under three nutrient systems. The growth and yield responses of rice crop to different sources of plant nutrients were variety specific. Alternative nutrient sources for synthetic fertilizers such as biofertilizer and liquid fertilizers were evaluated to develop nutrient supplement packages suitable for the selected rice varieties during 2013 *Yala* to 2014 *Yala* seasons separately. In addition, during 2014 *Yala* to 2016 *Yala*, series of pot and field experiments were conducted to assess the nutrient packages comprising levels of with reduced chemical fertilizers, organic fertilizers and selected microbial inoculants. The NUE of rice varieties as calculated based on N uptake of non-fertilized control varied from 10.8% to 21.9% for chemical fertilizers and from 1.9% to 26.8% for organic fertilizers. Two varieties, *Bg 379-2* and *Bg 94-1* showed comparable NUE for chemical and organic inputs whereas the rest of improved varieties showed higher NUE to chemical fertilizer inputs than to organic fertilizer inputs. Varieties *Bg 300*, *Bg 358*, *Bg 360* and *At 362* gained equally higher yields in soils managed with organic and chemical fertilizers.

Populations of rhizosphere bacteria differed among tested rice varieties and the highest population of total and N fixing bacteria were recorded for *Suduheenati* (128 x 10⁶ and 6 x 10⁶ CFU g⁻¹ soil) and *Madathawalu* (102 x 10⁶ and 4 x 10⁶ CFU g⁻¹ soil). Low inherent rhizosphere bacteria populations found in the rhizosphere of *Kaluheenati* and *Suwandal* with 0.5x10⁶ and 0.1x10⁶ CFU g⁻¹ soil, demonstrated a necessity for inoculation with bacterial inoculants to enhance yield. There was an increase in the rhizosphere bacteria population of *Bg 358* due to application of organic fertilizer suggesting possibilities for yield enhancement with bacterial inoculation under OF system. Under controlled condition, *Beijerinckia fluminensis* / *Rhizobium pusense* enhanced growth and yield of *Kaluheenati* by 80% and 57% when added alone with compost, and compost + chemical fertilizer, respectively. A significant yield increase by 65% was recorded for *Suwandal* in treatments inoculated with *Pseudomonas aeruginosa* and grown with compost and chemical fertilizers over non-inoculated treatments. *Rhizobium pusense* strain 76 enhanced the growth and yield of *Bg 358* by 128% and 63%

when treated with compost or compost and chemical fertilizer in combination respectively. Under field conditions, three inoculants *Beijerinckia fluminensis*, *Rhizobium pusense* and *Pseudomonas aeruginosa* led to a significant increase in plant N contents of respective varieties at maximum tillering / panicle initiation (PI) stages in comparison to non-inoculated control implying that those N fixing bacteria were able to survive and fix N under field conditions. In *Kaluheenati*, the highest plant N content (3.73% and 4.01%) was reported for the inoculated treatments added along with 80% compost with or without foliar nutrient supplement. *Pseudomonas aeruginosa* was effective in providing N to *Suwandal* at PI stage when added along with composts. Plant N contents of variety *Bg 358* at the maximum tillering stage was 3.52% - 3.89% when added with 80% compost but the impact was non-significant at the PI stage. Irrespective of positive impacts on the N contents, contribution of N fixing bacteria to yield increases was not significant in all varieties at the field condition. The impact of N fixing bacteria on yields of selected rice varieties needed to be further evaluated with different N input levels under field conditions.

2023- MPhil

45. BIOACTIVITY STUDIES AND PREBIOTIC CHARACTERISTICS OF COCONUT TESTA FLOUR OF SELECTED SRI LANKAN COCONUT CULTIVARS

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Abstract

Coconut testa is a by-product of the coconut industry, which is currently used for oil extraction. When subjected to oil extraction, an edible grade partially defatted testa can be obtained. The partially defatted residue of testa is underutilized despite being able to convert it into coconut testa flour (CTF). This study aimed to assess phytochemicals, bioactivities and prebiotic potential of CTF obtained from five selected Sri Lankan coconut cultivars namely, Gon Thembili (GT), Ran Thembili (RT), San Ramon (SR), Tall×Tall (TT) and commercial hybrid (COM). Mid-IR spectral characterization of CTF and their different fractions and admixtures was also a part of this study. CTF of individual cultivars was sequentially extracted with hexane, ethyl acetate (EtOAc) and methanol (MeOH). The total phenolic content (TPC), total flavonoid content (TFC), ferric reducing antioxidant power (FRAP), DPPH radical scavenging activity, α -amylase, α -glucosidase and lipase inhibitory activities, cytotoxicity and antifungal activity were assessed *in vitro*. The phytochemical profiling of CTF was done using ultra-high pressure liquid chromatography coupled with mass spectrometry. The bio-molecular distribution was characterised using Fourier transform infrared (FTIR) spectroscopy followed by chemometric evaluation. The total dietary fiber (TDF), soluble dietary fiber (SDF), insoluble dietary fiber (IDF) and crude fiber (CF) contents of CTF were determined as a part of the prebiotic potential evaluation. The degree of hydrolysis of crude polysaccharides (CP) of CTF was evaluated against simulated human gastric juice. Results showed that MeOH extracts of all cultivars displayed significantly ($p < 0.05$) higher TPC, TFC, antioxidant and α -amylase inhibitory activities. Among the cultivars, GT exhibited the highest TPC (102.48 ± 3.46 mg GAE/g), TFC (63.49 ± 4.47 mg CE/g), FRAP value (1097.23 ± 1.24 μ mol FeSO₄ /g), DPPH radical scavenging activity (IC₅₀, 45.37 ± 1.94 ppm) while TT resulted in the highest α -amylase inhibitory activity (IC₅₀, 80.09 ± 4.67 ppm). The EtOAc extract of TT showed the highest α -glucosidase inhibitory activity (IC₅₀, 7.82 ± 0.40 ppm). The distribution of phenolic constituents was found to vary among the different cultivars. The hexane, EtOAc and MeOH extracts of CTF of different cultivars showed low to moderate cytotoxicity (LC₅₀ > 2000 ppm) towards *Artemia salina*. Meanwhile, only hexane and EtOAc fractions of the COM cultivar showed antifungal activity against *Cladosporium cladosporioides*. FTIR analysis of crude extracts explicated that hexane and EtOAc extracts mainly contained lipid molecules, additionally, EtOAc extract contained phenolic constituents in minor quantities. MeOH extracts contained phenolic constituents and carbohydrates in larger quantities. Principal component analysis (PCA) of FTIR data discriminated the extracts with 99% of the total variance. Partial-least-squares (PLS) regression explicated a strong correlation between the α -glucosidase inhibitory activity and hydroxyl spectral regions of phenolic and alcoholic constituents. The results of FTIR analysis of CTF admixtures showed that the spectral bands were indicative of organic functional groups associated with fat, protein, carbohydrates and moisture. PCA resulted in clear discrimination among flour samples with a total variance of 97%. The PLS regression showed precise results in developing predictive statistical models for the determination of fat, protein and carbohydrate contents of CTF. The range of TDF, IDF, SDF and CF was found to vary from 68.74 ± 0.80 - 72.87 ± 0.58 , 53.18 ± 0.31 - 55.85 ± 0.27 , 13.65 ± 0.55 - 18.05 ± 1.27 , 16.88 ± 0.83 - 21.35 ± 1.39 g/100 g on a moisture-free and fat-free basis respectively with no significant difference ($p > 0.05$) among the cultivars. Meanwhile, the rate of hydrolysis CP of all cultivars was very low (2.75-5.48 %) indicating high resistance toward simulated gastric juice. This study concludes that the CTF is a potent source of bioactive compounds that claim various bioactivities and possess potential prebiotic attributes. The results of this study would provide the necessary impetus

for further chemical studies on authentication, product development and nutrition of CTF obtained from local coconut cultivars.

46. PRODUCTIVITY AND EFFICIENCY CONSIDERATIONS IN THE VILLAGE TANK CASCADE SYSTEMS OF SRI LANKA: A CASE IN MAHAKANUMULLA VILLAGE TANK CASCADE SYSTEM

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Abstract

The Sri Lankan village tank cascade system is identified as a globally important agricultural heritage system (GIAHS) in 2018, due to its unique technology, sustainability, and resilience to natural disasters. For more than 2000 years, these systems have accounted for a significant contribution to the paddy production in Sri Lanka. Even though multiple studies have been carried out on the ecology, evolution and current issues of village tank cascade systems, a systematic benchmark of the productivity and efficiency of these systems has not taken place to date. Therefore, the thesis analyses three separate studies on water productivity and technical efficiency of village tank cascade systems with a systematic review on tank rehabilitation. The first and second studies were conducted in the *Mahakanumulla* tank cascade system to assess the agricultural water productivity and technical efficiency of the paddy production in village tank cascade systems collecting data from a structured questionnaire survey. The study results indicated average water productivity in the cascade to be in a satisfactory level with the extent of command area and crop losses being determinants of agricultural water productivity. The technical efficiency study highlighted comparatively low technical efficiency values in *Yala* season compared to the *Maha* season. The results of the stochastic production function indicated seed paddy, labour, machinery usages and land extent have significant positive impact on paddy yield while fertilizer use showed a negative impact. The results of the inefficiency model suggested that the command area cultivated, farming being the only income source, receiving government subsidies and the support from farmer organizations have a significant positive relationship with technical efficiency in both seasons. Both studies implied the water scarcity in the cascade tanks due to poor rehabilitation. Therefore, the third study was conducted to assess the factors affecting the success of tank rehabilitation projects, as an evaluation of 48 studies in tank rehabilitation through a meta-analysis. 68% of Sri Lankan tank rehabilitation projects and 40% of Indian projects found to be unsuccessful based on B/C ratios of tank rehabilitations. The results of the study revealed that the rainfall, farmer participation and activities performed in tank rehabilitation have significant positive impacts on the B/C ratio in tank rehabilitation projects.

47. **RESOURCE USE EFFICIENCY AND ENVIRONMENTAL SUSTAINABILITY IN DRY ZONE OF SRI LANKA: AN ASSESSMENT USING A BIO-ECONOMIC MODEL IN MAHAKANUMULLA VILLAGE TANK CASCADE SYSTEM**

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Abstract

Village Tank Cascade Systems (VTCSs) were built in ancient Sri Lanka as self-reliant and climate-resilient agro-ecological systems. This study examined crop choices and profitability of farming and environmental sustainability under alternative rainfall regimes in *Mahakanumulla* VTCS located in the Anuradhapura district. A bio-economic model was developed to represent farming activities in the VTCS for the 2018-19 *Maha* and 2019 *Yala* seasons using data gathered from secondary sources and a key informant survey. The baseline equilibrium was calibrated by treating farmers as profit cultivating four types of land (uplands and lowlands in *Maha* and *Yala* seasons), using two types of labor (hired and family), and twelve-monthly water constraints. Six different models were developed by treating six sub-divisions of VTCS as different agricultural systems considering the water management hierarchy of the VTCS. The models were simulated under alternative rainfall regimes, market interventions and technological interventions. The optimal crop mixes, farm profits, and shadow prices of resources associated with the baseline scenarios were compared with those of counterfactual scenarios. The results of the analysis clearly illustrated that water and labor are the key determinants of the system. VTCS has annual profitability of 111 million LKR under normal environmental conditions, cultivating the 922 ha of lowlands and 205 ha of uplands per annum. However, the profit results reflected that the drought has resulted in a drastic reduction of profit to the VTCS and avoided cultivations in the *Maha* season. Year around drought caused 77% profit reduction compared to the baseline and it was 47% under *Maha* drought. The introductions of the buyback arrangement of chilli, and maize have maximized the profitability of the current cropping pattern and can restore profitability loss under extreme climate scenarios. Similarly, partial desiltation enhances the profitability of the system along with the eco-system services provided by VTCS. However, the project worth results of the tank desiltation demonstrate clearly that the traditional crop choices cannot generate sufficient revenue to cover the cost of desiltation and that it has to be coupled with a market intervention to make the investment worthwhile. Further, policy decisions towards climate adaptation and eco-system conservation would drive towards the rehabilitation of VTCSs in Sri Lanka.

48. MULTIPLICATION OF *Madhuca longifolia* (MEE) AND *Manilkara hexandra* (PALU), BY PLANT TISSUE CULTURE METHODS

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Abstract

Forest degradation is increasing at an alarming rate mainly due to several anthropogenic activities and under the Sri Lankan context, dry and intermediate forests suffer extensively. As a solution, two canopy dominant tree species, *Manilkara hexandra* and *Madhuca longifolia* having higher reforestation potential in the dry zone of Sri Lanka are selected to study seed germination and application of tissue culture techniques to increase the number of propagules. *M. longifolia* seeds contain physical dormancy that can be overcome by mechanical scarification. Soaking in GA3 (gibberellic acid), KNO₃ (potassium nitrate) and distilled water (DW) also increased the *ex vitro* shoot growth. Treating *M. hexandra* seeds with GA3 was the best for early germination and high percentage of germination. The seeds contain endogenous dormancy, or a combination of physical and physiological dormancy. Accordingly, *ex vitro* germination after pre-treatments is recommended for both the species.

For tissue culture under *in vitro* conditions, an effective sterilization protocol was developed for each species separately. Combination effect of Clorox (NaOCl - sodium hypochlorite) along with mercuric chlorite (HgCl₂) increased the survival rate of all the explants than using Clorox alone. Maturity of the explant affected the load of contaminants. For every explant, there is a threshold limit to withstand the strength of sterilant and to retain its viability. As another technique, micropropagation was performed where the apical shoots of *M. longifolia* was best suited for early bud break and rapid elongation than the nodal explants; this was negligible in *M. hexandra*. Higher percentage of shoots induced new buds with BAP in both the apical and nodal explants of *M. longifolia*. In addition, incorporation of coconut water with ½ MS was best with BAP. *M. hexandra* requires addition of kinetin to BAP to enhance shoot initiation and elongation. Incorporation of other cytokine or auxin had a better performance on shoot multiplication than use BAP (6-benzylamino purine) alone. Also, GA3 stimulated *M. longifolia* to proliferate more shoots. The effect was intensified together with zeatin and BAP. In species *M. longifolia*, pulsing with indole-3-acetic acid (IAA) stimulated roots within lowest time duration and growing shoots in IAA incorporated media produced multiple roots. To obtain higher survival, *in vitro* root induction and growth can be recommended for *M. longifolia*. However, with regard to the cost and the feasibility, *ex vitro* rooting and acclimatization can be recommended. For *M. hexandra*, rooting under *in vitro* conditions on ½ MS media with IBA, IAA and NAA can be recommended. Before training the plants into soil media pre-culture of rooted plants on ¼ MS liquid media increased the survival rate when transferring into sand media under greenhouse conditions. The results reflect that these findings can be implemented in rapidly expanding field of forestry where micro-propagated planting materials can be used for the reforestation programmes in the dry zone.

2023- PhD

49. PROCESSED FOOD TRADE IN SOUTH ASIA: AN ANALYSIS OF PATTERNS, POTENTIAL AND BARRIERS

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Abstract

This thesis research examines patterns, potentials, and barriers to processed food exports in Bangladesh, India, Pakistan, and Sri Lanka. The thesis consists of context information on trends and patterns of processed food trade from South Asia and two main objectives using the computable general equilibrium modeling and Gravity model to focus on a comparative analysis of different countries in South Asia aimed at tackling some important aspects of trade issues of processed food. The first objective investigates the potential effects of trade policy changes on the export of processed food from South Asia. The second objective estimates the effects of Non Tariff Measures (NTMs) on the export of fruits from South Asia. Using trade indicators namely Herfindahl-Hirschman Index (HHI), Revealed Comparative Advantage (RCA), Trade Intensity Index (TII), Nominal Protection Coefficient (NPC), Effective Protection Coefficient (EPC), and Domestic Resource Cost (DRC), the context chapter examines trends and patterns of processed food trade paying special attention to export diversification, comparative advantage, and competitiveness of processed food industries in South Asia. The results show that most South Asian countries have a large potential to produce and export processed food (e.g., edible oil, flour and cereals, preserved fruits and vegetable, and meat) and they have been successful in acquiring new markets and exporting new products. Using the Global Trade Analysis Project (GTAP) model version 10, the first objective firstly investigates the associated welfare and trade effects under different trade agreements that can be adopted by the governments of South Asia. The study uses various trade agreement options (i.e. Preferential Trade Agreements (PTAs), Free Trade Agreements (FTAs) within the region/with the United State of America (USA), China, United Arab Emirate (UAE), and European Union (EU) as a development policy to increase social welfare and improve the trade of processed food in this countries. It was found that all PTAs scenarios (50% reductions in import taxes on processed food) caused an improvement in social welfare, domestic price, industrial production, and exports of processed food particularly meat, edible oil, processed rice, fish, and dairy products except liberalization of EU in Bangladesh. FTAs with the USA, EU, and within the region have improved the welfare in India, Pakistan, and Sri Lanka, while the FTAs with China decreased welfare. The propensity to import has exceeded the propensity to export under FTAs scenarios in South Asian countries. However, a negligible increase in the export of processed food was observed in Sri Lanka and India under FTAs scenarios with the EU and within the region. The overall effect of getting a concession from the Generalized System of Preferences (GSP) from developed countries particularly the EU was a largely beneficial and better strategy than forming FTAs for the exporters of processed food in South Asian countries. Secondly, evaluate the associate welfare and trade effects of the policy response to crises like COVID-19 using various trade policy options (i.e. 25 percent unilateral import liberalization by China and Saudi Arabia, 10 percent unilateral export restriction by India and Pakistan on processed food Vs. all trade options). The results show that import liberalization improves global welfare while introducing export taxes depresses global welfare. Moreover, an improvement of 835 USD million, if all four policy changes are made simultaneously, will be observed in South Asia. It was found that import liberalization caused an increase in industrial production and exports of processed food and agricultural products in Bangladesh, India, and Sri Lanka. In contrast, the export restriction scenarios caused a reduction in their industrial production and exports of processed food in India and Pakistan and an increase in other South Asian countries. The overall effect of the policy response to COVID-19 by major trading partners was largely beneficial for exporters of processed food in South Asian countries. The second objective of this thesis firstly uses

the Gravity model to determine the effects of NTMs on fruit exports from Bangladesh, India, Pakistan, and Sri Lanka during the 2001-2018 period. Secondly, the uses of Ad Valorem Equivalent (AVEs), compare the tariff equivalent of NTMs among the selected countries. An increased tendency towards NTMs has been observed in most countries in recent years. The most widely applied NTMs were technical measures, followed by price control, and quantity restrictions, while fresh fruits tended to be relatively more regulated than processed fruits. The results of the gravity model depicted the mixed effect of specific NTM categories on fruit exports from South Asian countries. Technical Barriers to Trade (TBTs), Sanitary and Phytosanitary (SPSs), Price Control Measures (PCs), and other measures were the most significant measures that negatively affected the export of fruits from South Asia. The negative effect of TBTs was decreasing, while it was increasing on SPSs. The results depict that the effects of NTMs on trade flow range between 9% and 598% for fruits, compared to the effects of tariffs. Overall, this objective sheds light on an under-researched aspect of trade liberalization: the proliferation and increase of NTMs and the negative effect of TBTs and SPSs in most South Asian countries. Greater attention needs to be given to NTMs by trade negotiators, policymakers, and multilateral agencies such as the World Trade Organization, World Bank, and International Monetary Fund (IMF).

50.

**DEVELOPMENT OF ECONOMICALLY VIABLE RAPID
IN VITRO PLANT PRODUCTION PROGRAMME FOR NEW CULTIVARS OF TEA
(*Camellia sinensis* (L.) O. Kuntze).**

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Abstract

Commercial exploitation of tea (*Camellia sinensis* (L.) O Kuntze) micropropagation is hindered by low and variable multiplication rates among tea cultivars. Hence, this study intended to evaluate multiplication rates of newly improved tea cultivars and to identify optimum growth regulator combinations and culture conditions for increasing multiplication rates to a commercially viable level. Stem nodal cuttings of TRI 5004 cultivar were inoculated on MS (*Murashige and Skoog*) medium and generated sufficient microshoots for the experiments. Microshoots were subcultured to the nine liquid media supported by floral foam and solid medium (MS + 0.5 mg/L IBA + 3 mg/L BAP) was used as the control. Twelve weeks after subculturing, significantly highest average microshoots number per shoot were recorded (4.8) in MS + 5 µm TDZ + 10 µm NAA liquid medium and highest relative height growth was recorded (69%) in MS + 0.1 mg/L IAA + 1 mg/L BAP + 0.2 mg/L GA3 liquid medium. The experiment was repeated under fully liquid submerged conditions and data were recorded at four, ten and fourteen weeks and highest average microshoots number per shoots (2.6, 4.4 and 6.9) and higher relative height growth rates (27%, 51% and 69%) were recorded in the same medium. Improvement in the rate of shoot proliferation and relative height growth rates in liquid media compared to solid media, clearly showed the potential for developing a commercially viable liquid culture protocol for mass production of planting materials in tea improvement programmes. Somatic embryogenesis is an efficient micropropagation technique for mass multiplication of tea plants. Optimization of protocols is necessary for somatic embryo induction, development, multiplication and regeneration of plantlets for various explants of tea. The present study was conducted using cotyledon-derived somatic embryos, leaf and stem nodal callus of TRI 5001 tea cultivar as explants and liquid dynamic Murashige and Skoog (MS) media supplemented with different growth regulator combinations were tested against solid MS medium. Significantly higher cotyledon-derived somatic

embryo multiplication rate was observed in MS medium supplemented with 3 mg/L TDZ. Leaf callus proliferation, compact and embryonic callus formation was comparatively higher in MS medium containing 1.1 mg/L TDZ and 1.86 mg/L NAA. Subsequently somatic embryo formation was observed in MS medium supplemented with 0.1mg/L NAA, 1mg/L BAP and 0.2 mg/L GA3. Higher stem nodal callus proliferation and compact callus formation were recorded in MS containing 0.11 mg/L TDZ, and 0.1 mg/L IBA and higher embryonic callus formation was observed in MS medium supplemented with 0.1 mg/L TDZ and 1.86 mg/L NAA. Plant regeneration was achieved from somatic embryos formed from cotyledons on MS medium supplemented with 3 mg/L BAP and 0.1 mg/L NAA. The liquid dynamic MS medium supplemented with different growth regulator combinations was useful in developing efficient somatic embryogenic protocols from cotyledon- derived somatic embryos, leaf and stem nodal callus of tea for mass multiplication. Tea is conventionally propagated by vegetative cuttings. Even though it is the mostly adopted practice commercially in Sri Lanka, annual planting material requirements cannot be fulfilled due to the unavailability of sufficient number of shoots as well as due to erratic weather pattern and pest and disease incidences. Photoautotrophic micropropagation techniques are considered as a rapid mass propagation method in woody perennials. However, potential of photoautotrophic micropropagation techniques have not been explored for tea at a commercially viable level. This study was focused on developing a photoautotrophic (PA) micropropagation technique to increase growth and multiplication with minimum contamination. Microshoots of TRI 5000 series cultivar were established on liquid MS media with 5 μ m TDZ + 10 μ m NAA growth regulator combination under different light intensities and qualities with LED light system. Inoculation after 12 weeks, recorded the highest average number of microshoots per shoot (6.2) in 15g/L sucrose MS liquid medium under 75 μ mol photons m⁻²s⁻¹ Photosynthetic Active Radiation (PAR) light intensity with R: G: B 1:1:1 light quality. Higher relative height growth (133%) was observed in 100 μ mol photons m⁻²s⁻¹ light intensity with R: G: B 1:1:1 light quality. Identified light quality and quantity combinations can be used to obtain a large number of tea microshoots at Rs.3.90/Plant under photomixotrophic conditions compared with Rs.7.00/plant under conventional heterotrophic conditions.