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EDITORIAL

The Importance of Scientific Conferences

I have just returned from attending the XXIV World Congress of the International Union of Forest Research Organizations (IUFRO) at Salt Lake City where some 2000 participants from all over the world attended. IUFRO is "the" global network for forest science and research cooperation. It unites more than 15,000 scientists in almost 700 Member Organizations in over 122 countries, and is a member of ICSU. Scientists cooperate in IUFRO on a voluntary basis.

Besides keynote plenary speeches by well-known respected figures in their fields there were also many concurrent technical sessions and an industrial exhibition. The International Forestry Students Association was an active participant and an interesting quiz was held for forestry students at Universities.

I raise this issue as the subject of this editorial as I consider and as scientists and researchers, one must attend such international conferences that are organized by respected and recognized international institutions that the Government must make it a policy to support Malaysian participation. There are so many benefits of attending such conferences.

Only ten Malaysians attended this Congress which was unfortunate but no leaders of research institutions or University deans were present. There were less than five scientific papers by Malaysian researchers at the congress which is again a real disappointment.

I was told that there were not enough funds and the bureaucracy of getting approvals to attend international meetings prevented many who had wished to attend.

In my report on the Congress, I made a number of recommendations that basically said that Malaysia must make it a policy and a priority to be actively involved in similar international organizations such as IUFRO, especially when these organizations are scientific and research oriented in nature and are apolitical.

Adequate financial support should be given to member institutions for their scientists to be actively involved in international scientific activities and Congresses. Top leaders of research Institutions and Universities must make it a point to attend all future IUFRO Congresses and their participation be fully supported by Government in order to establish networks with other international organizations.

Malaysian research institutions and universities should maximise the opportunities provided by international organizations for human resource management and training, technical support and networking to improve and enhance research in the country. More young researchers should be given the opportunity to attend such world congresses so that they be exposed to the current research findings and activities in the world and provide opportunities for networking. In this present global world, we cannot afford to stay isolated from what is going on internationally in the scientific world. While one can depend on the internet and other media, there is nothing more useful than face to face contacts. Moreover, it is critically important that Malaysians are not only seen but heard. Malaysians who attend must express their views from the floor so that Malaysia is recognized. They should not just attend as silent participants. Malaysian scientists and the Malaysian Government must support attendance at such conferences so that the Malaysian flag is held high and Malaysian scientists be respected internationally. The example created by Professor Tan Sri Dr Zakri Hamid should be emulated by more.

Salleh Mohd. Nor
Co-Chairman, JOSTT

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Growth performance and root characteristics of young immature rubber clones (*Hevea brasiliensis*) in relation to size of nursery bag

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Abstract Rubber planting has shifted to the drier marginal land. This can give rise to a higher mortality rate during field transplanting, requiring immediate replacement of dead plants. Establishment of an advanced planting material (APM) nursery will be a good solution. Therefore, this study was carried out to evaluate two *Hevea* clones, RRIM 2025 and RRIM 3001 using small (10 cm × 25 cm) and large (31 cm × 36 cm) polybags. Plant height and stem girth were highest in the large polybag. The dry weights of both root and shoot for both clones were strongly affected by smaller sized polybag. The root to shoot was significantly higher in small polybags compared with large polybags. Root length and root volume were also significantly influenced by polybag. This suggests that a reduction in polybag size caused a decline in growth performance as reflected by the growth rate of *H. brasiliensis* at the nursery stage. It was concluded that a large polybag resulted in vigorous performance for rubber seedlings, and that it would be ideal for use in raising young-budded *Hevea* tree as advanced planting material before establishment in the field.

Keywords rubber – advanced planting material – polybag size – nursery – rooting characteristics

INTRODUCTION

Hevea brasiliensis or rubber is a native of Brazil, and was introduced into Malaysia in 1895 from the Botanical Gardens in Singapore. It grows well in deciduous rainforest regions of lowlands with temperature ranging from 21–35°C and a well distributed rainfall of 2000 mm or more, and on a well-drained soil [1, 2]. The planted area of *H. brasiliensis* nowadays has expanded to all over the country in the face of escalating automobiles industry in the world. This situation is propelling the search for alternative planting areas, especially in drier marginal areas, to meet the increasing industry demand for natural rubber [3].

Global warming has become a major issue in rubber cultivation especially the ability of young rubber trees to withstand drought and limited water in marginal land [4]. As a result of limited land and the challenge of global warming, many plantation nurseries face a short supply of planting material. Usually, the mortality rate of rubber seedlings during transplanting is about 10 to 20 percent. Therefore, the polybag nursery system was introduced to prepare planting material for transplanting into the field. Older planting materials are also used for replacing dead seedlings after field transplanting. The selection of suitable polybags should be given attention to achieve good performance [5].

In general, the size of the polybag increases plant leaf area, shoot and root biomass, and also affects the soil volume available for plant growth [6]. That plants undergo many physiological and morphological changes in response to reduced soil volume has been reported for a wide range of crops, showing response differences between species, and even between cultivars within a species. As soil volume is different between two polybags of different sizes, it can have pronounced effects on the growth of plants resulting from root restriction [7].

Previous research showed that a small polybag causes growth reduction which in turn inhibits leaf elongation [8], stem increment [9], photosynthesis [10], changes in dry matter partitioning within the plant [6], nutrient uptake [11] and hormone metabolism [12]. Shoot growth is a major factor controlling the intensity of root growth when soil temperature and soil water are non-limiting [13]. Although polybag size obviously affects the growth of plants, little research has been done on perennial species, such as rubber. It is therefore very important to determine how the polybag size will affect the growth of *Hevea* clones. This study was carried out to determine the effects of the size of polybags on the growth and rooting characteristics of *Hevea* clones.

MATERIALS AND METHODS

Plant materials and experimental treatments

This study was carried out under a rain shelter in Field 2 of the Faculty of Agriculture, Universiti Putra Malaysia. The source of rubber clones was from Malaysian Rubber Board (MRB) consisting of three month rootstock from clones RRIM 2025 and RRIM 3001. The plants were selected according to the average height and girth. Clones RRIM 2025 and RRIM 3001 are classified as Latex Timber Clones (LTC) which have characteristics of high production of both latex and rubber wood [14]. Vegetative propagation of these clones is usually done by bud grafting. Two standard black polybags size were used, *viz*, small (S): (7" width × 10" length) and large (L): (20" width × 20" length) for the polybag nursery. The small and large polybags were filled with 20 kg and 40 kg of soil, respectively. The soil used was from the Munchong Series (USDA soil taxonomy: *Typic Hapludox*; FAO/UNESCO Legend: *Haplic Ferralsol*). This is a clayey soil with a yellowish brown to strong brown colour [15]. The soil was sieved through a mesh (2.00 mm) to remove debris and stones. The plants were watered once in two days to maintain soil moisture close to field capacity [16] and were fertilized once in two months to enhance fertility of the soil medium [17]. A fertilizer containing 10.7% N, 16.6% P and 9.5% K as recommended by the Rubber Industry Development Authority Malaysia (RISDA) [18] was used.

Data collection

Height: plant height was measured every month for four months from the soil surface to the tip of the plant shoot.

Girth: plant girth was measured at 15 cm from the soil level.

Total leaf chlorophyll content: data were taken using a portable chlorophyll meter SPAD-502. The chlorophyll meter was calibrated each time by pressing the measuring head close without inserting a leaf. Measurements were made on 10 randomly selected, mature and completely expanded leaves near the shoot apex per treatment.

Dry weight: destructive samples were separated into leaves, stems, and roots, then, dried in an oven at 50°C for 48–72 hours. Thereafter, the weight of plant parts was determined using a weighing scale.

Root shoot ratio: the root-shoot ratio was calculated from the dry weight of roots divided by sum of dry weights of leaves and stems.

Root length and root volume: the roots were inserted to the suitable tray and water was filled up to half full of the tray. Then, the scanner (model HP ScanJet 4c, Hewlett-Packard Co., USA) head was closed and root was scanned using a WhinRhizo program version 4.0 B [19]. The colour was defined between the root and the background to identify the colours of the objects to be analyzed and those of the surrounding background.

Leaf nutrient content: The dried leaves were ground and sieved (<2 mm mesh). The ground sample was placed into a 75 mL digestion tube and 5 mL sulphuric acid (H_2SO_4) was added, after which the contents of the tube were digested on a hot plate at 450°C for 7 minutes in a fume chamber. Ten milliliters of hydrogen peroxide (H_2O_2) were then added and the solution digested for another 4 minutes until a clear solution appeared indicating complete digestion of the sample. The solution was filtered and made up to 100 mL in a volumetric flask. Nitrogen (N), phosphorus (P), potassium (K), and magnesium (Mg) were then analyzed by an atomic absorption spectrophotometer (Perkin Elmer, Model AAS 3110).

RESULTS

There was no significant difference between the two clones in large polybags for plant height but small polybags significantly inhibited plant height in both clones. The plant height increased higher in the large polybag than in the small polybag over time (Fig. 1). T2 had the tallest plants while the shortest plants were in T3. Girth of the plants in the large polybags was significantly bigger than in the small polybags for both clones (Table 1). There was no significant difference between T2 and T4 for girth.

Leaf dry weight showed significant differences between polybag sizes. Leaf

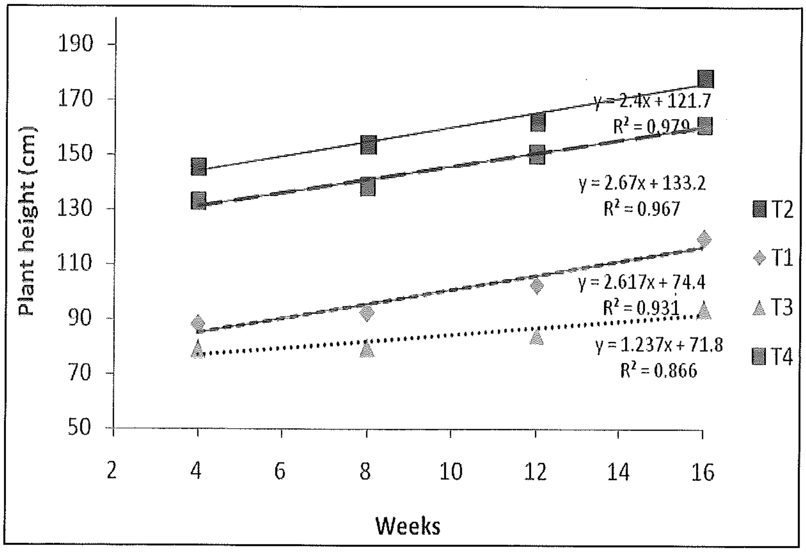

Figure 1. Plant heights of clone RRIM 3001 and clone RRIM 2025 over time in polybags of different sizes. T1 – small polybag, RRIM 3001; T2 – big polybag, RRIM 3001; T3 – small polybag, RRIM 2025; T4 – big polybag, RRIM 2025.

Table 1. Effect of polythene bag size on plant height, leaf, stem, root dry weights and root to shoot ratio of clones RRIM 3001 and RRIM 2025. T1 – small polybag, RRIM 3001; T2 – big polybag, RRIM 3001; T3 – small polybag, RRIM 2025; T4 – big polybag, RRIM 2025.

Treatment	Plant height (cm)	Girth (cm)	Leaf dry weight (g)	Stem dry weight (g)	Root dry weight (g)	Root/ shoot ratio
T1	119.50 b	9.80 b	0.012 c	0.016 c	0.15 b	5.179 a
T2	178.30 a	13.70 a	0.028 a	0.081 a	0.28 a	2.587 b
T3	93.80 c	7.20 c	0.009 c	0.013 c	0.10 b	4.727 a
T4	161.10 a	12.10 a	0.022 b	0.068 b	0.28 a	3.067 b
LSD (0.05)	23.85	1.90	0.005	0.007	0.03	0.04

dry weight of clone RRIM 3001 was higher than for clone RRIM 2001 only in the large polybags. Similarly, the large polybags produced significant difference in stem dry weight, but no significant difference was observed in the small polybags between the two clones (Table 1). Large polybags encouraged vigorous root growth compared with small polybags, irrespective of clone. This suggests that root weight was closely associated with the size of polybags. Comparing between the clones, shoot, stem and root dry weight of clone RRIM 3001 were generally higher than those of clone RRIM 2025. When compared with small polybags, the root to shoot ratio in the large polybags decreased by 50.0 % and 35.1% for clones RRIM3001 and RRIM 2025, respectively (Table 1). The highest root to shoot ratio was observed in T1. It would appear that plant shoot growth was inhibited more in small polybags than the roots despite the restricted rooting space, increasing root to shoot ratio in both clones.

Root length increased with the size of the polybag as shown by T1 and T3 *vs* T2 and T4. Root length was significantly higher in clone RRIM 3001 than in RRIM 2025 for both polybag sizes (Table 2). Root elongation was more rapid in the large polybag than in the small polybag over time (Fig. 2). Root length also decreased as root volume decreased. Root volume increased significantly by 94.7% and 110.5% for clones RRIM 3001 and RRIM 2025, respectively, when switching from small to large polybags. RRIM 3001 was superior in terms of root length and root volume increment compared with RRIM 2025 when planted in polybags of different sizes.

Leaf chlorophyll content was significantly higher for plants in the large polybags but was lower in the smaller polybags by 13.8% and 12.1% for clones RRIM 3001 and RRIM 2025, respectively. The highest chlorophyll content was observed in T2.

The major leaf nutrients N, P and Mg responded significantly to polybag size except for K which showed non-significant increases. A larger polybag size

Table 2. Effect of polybags size on root length, root volume and leaf chlorophyll content of clones RRIM 3001 and RRIM 2025. T1 – small polybag, RRIM 3001; T2 – big polybag, RRIM 3001; T3 – small polybag, RRIM 2025; T4 – big polybag, RRIM 2025.

Treatment	Root length (cm)	Root volume (cm^3)	Leaf chlorophyll content (SPAD unit)
1	1921.9 c	36.68 c	52.70 b
2	3410.9 a	71.42 a	61.10 a
3	1586.4 d	30.58 c	51.60 b
4	3054.7 b	64.38 b	58.70 a
LSD (0.05)	316.51	5.37	2.65

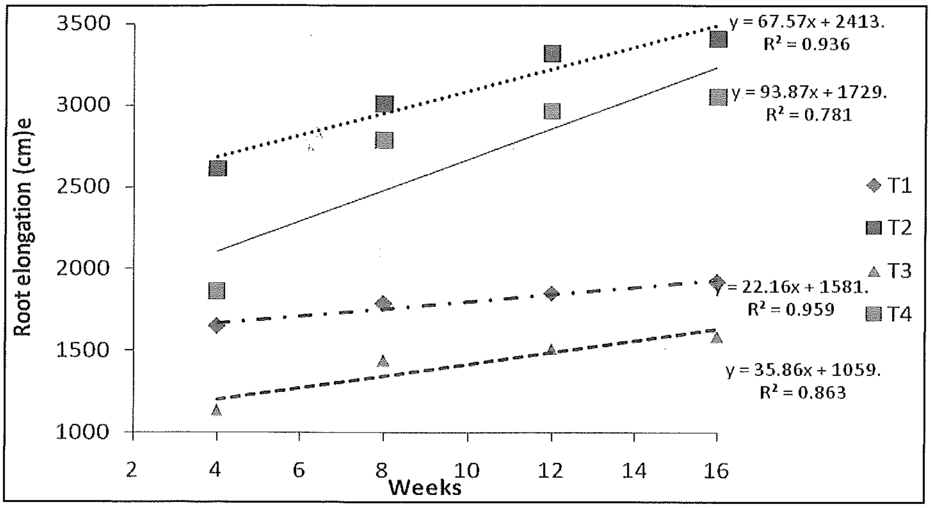

Figure 2. Linear relationship between root elongation and time in clones RRIM 3001 and RRIM 2025 grown in polybags of different sizes. T1 – small polybag, RRIM 3001; T2 – big polybag, RRIM 3001; T3 – small polybag, RRIM 2025; T4 – big polybag, RRIM 2025.

Table 3. Leaf nutrient contents of *Hevea* clones in polybags of different sizes. T1 – small polybag, RRIM 3001; T2 – big polybag, RRIM 3001; T3 – small polybag, RRIM 2025; T4 – big polybag, RRIM 2025.

Treatment	N	P	K	Mg
1	2.293 b	0.093 c	1.380 ab	0.120 c
2	2.747 a	0.170 a	2.027 a	0.273 a
3	1.830 c	0.083 c	1.080 b	0.090 c
4	2.520 ab	0.127 b	1.747 ab	0.200 b
LSD (0.05)	0.438	0.028	0.753	0.043

increased leaf N by 19.8% and 37.7% in clones RRIM 3001 and RRIM 2025, respectively (Table 3). The same trend was observed for P concentration which increased by 82.8% for clone RRIM 3001 and 53.0% for clone RRIM 2025 when polybag size increased from small to large. The content of Mg was low in both large and small polybags compared with the optimum ranges for Mg in rubber growing soils (range of 1.0 to 4.00 (meq/100 g) [20] and showed that this nurient was deficient, especially in the leaves.

DISCUSSION

The different sizes of the polybags showed significant effects on growth of bud-grafted rubber seedlings. The large polybag was able to sustain optimum growth rates of such characteristics as plant height and girth. Stem girth is the most important parameter in *H. brasiliensis* for evaluating the degree of maturity of the plant, especially in the field. Besides, increased girth shows that the stem is able to support an extended and heavy crown [14]. The findings from the current experiment are similar to that for woody nursery plants [21] which reported that height and crown diameter increased as the container size increased. In another species, *Red Sunset red* maple significantly better height and caliper growth were produced in large containers [22]. In the current study, large polybag resulted in higher dry weight of leaves, stems and roots. The larger polybag also produced taller plants and more vigorous shoots. A similar trend has been reported in *Jatropha curcas* which were grown in polybags [23].

Clone RRIM 2025 showed symptoms of nutrient deficiency and can be considered a less vigorous clone (Fig. 3). In contrast, clone RRIM 3001 grew healthy and strong due to a larger amount of fine roots available for the absorption of moisture and nutrients. In small polythene bags, both clones recorded increases in root to shoot ratio over the ratio in large polybags. The increase in root to shoot ratio is due to a decrease in biomass partitioning to the main shoot, thus, affecting shoot growth and development. This result agrees with an earlier study which indicated that increasing root to shoot ratio in barley was associated with the greater relative amount of assimilates allocated to the root when grown in

Figure 3. Clones RRIM 2025 and RRIM 3001 in different sizes of polybag.

small pots [21, 24]. These indicate that root/shoot ratio had favorable effect on both clones by accumulation of dry matter which was greater in root than in shoot for clone RRIM 3001 compared with clone RRIM 2025. Thus, this may help for more effective searching of water in deeper soil. Similarly, others have found that roots are shorter, thicker, and more irregularly shaped in root-restricted plants [25]. However, contrasting results have been reported indicating no significant difference in root to shoot ratio of *Averrhoa carambola* with respect to varying container size [26]. The authors stated that dry matter was reallocated evenly to the root, shoot and stem when the plant was grown under stress and in unfavorable conditions.

A smaller polybag size produced a reduction in root length and root volume. Roots were thin in the small polybags and this could lead to less water uptake as reflected in a reduction in shoot growth. Increasing root elongation within a crop root system increases water and nutrient availability to the crop [27]. Reduction in root volume can also be related to a lack of nutrients and other morphological elements that impair root growth [25, 28]. Root development has great influence on the growth of the rubber tree and limiting it can reduce tree vigour effectively.

Comparing between clones, RRIM 3001 has the ability to produce a vigorous root system and would be suitable for planting over a wide range of soil conditions. Good vigour is one of the desired characteristics for *H. brasiliensis* to ensure early maturity and production of latex [14]. Chlorophyll content increased in the large polybag which means that the rate of photosynthesis would be higher, leading to increased stomatal conductance, therefore resulting in higher biomass production for both clones. A decline in leaf chlorophyll content in bell pepper in response to decreased rooting volume was coupled with reduced leaf photosynthesis rate [29]. The present finding is supported by earlier reports of a positive correlation between pot size and chlorophyll content [30]. Otherwise, the causes for the difference in growth may be the different water-holding capacity and different nutrient status of the soil medium. Leaf concentrations of N, P and Mg decreased in small polybag was associated with the reduced root length and root volume, showing a direct impact on nutrient uptake. However, reduced polybag size did not cause a significant change in K content. Even though nutrient concentrations were decreased, these nutrient levels were sufficient to support plant growth.

CONCLUSION

Clone RRIM 3001 showed better performance in terms of growth compared with clone RRIM 2025. This may be due to a successful breeding programme for LTC clones which resulted in the newer clone RRIM3001 being more hardy to withstand stress condition compared with RRIM2025. A larger polybag recorded the best performance in growth and should be considered for plant propagation in the nursery. However, some other aspects need to be considered, such as the length of time a plant remains in the polybag and the water-holding capacity of the medium to avoid the probability of root restriction and water stress occurring later. In conclusion, a large polybag is recommended for establishing an advanced planting material nursery for *Hevea* clones because it provides a better buffer to environmental stress.

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Trichosnathes wallichiana (Cucurbitaceae): a new host fruit of *Bactrocera tau* (Insecta, Tephritidae)

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Abstract *Bactrocera tau* was reared from the ripe fruit of *Trichosanthes wallichiana* (Cucurbitaceae) collected in University of Malaya campus. More male flies were recovered than female flies, but the ratio was not significantly different. The pupation period was 9 to 10 days, and the pupal mortality rate was 18.18%. This is a new record of host plant of tephritid fruit flies in general, and *B. tau* in particular. It is a new genus of host plant for Malaysia.

Keywords fruit fly – host plant – *Bactrocera tau* – *Trichosanthes* – Malaysia – new host record

INTRODUCTION

Bactrocera tau (Walker) is the most common tephritid fruit fly species of the subgenus *Zeugodacus* found in Southeast Asia [1]. It has been reported to infest a wide range of host fruits including several genera of cucurbits and many unconfirmed records [2]. The recorded host plants include *Benincasa hispida* (wax gourd), *Borassus flabellifer* (toddy palm), *Capsicum annuum* (bell pepper), *Citrullus lanatus* (watermelon), *Cucumis melo* (melon), *Cucumis sativus* (cucumber), *Cucurbita maxima* (giant pumpkin), *Cucurbita moschata* (pumpkin), *Cucurbita pepo* (ornamental gourd), *Dimocarpus longan* (longan tree), *Ficus racemosa* (cluster tree), *Luffa acutangula* (angled luffa), *Luffa aegyptiaca* (loofah), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Momordica charantia* (bitter gourd), *Passiflora edulis* (passionfruit), *Phaseolus vulgaris* (common bean), *Psidium guajava* (guava), and *Trichosanthes cucumerina* [3]. Specimens have also been reared from *Trichosanthes tricuspidata* [4]. The present report on *Trichosanthes wallichiana* constitutes a new host plant record of *B. tau*, and a new genus of host fruit in Malaysia.

MATERIALS AND METHODS

Ripe *T. wallichiana* fruits (Fig. 1) were collected from wild plants in the University of Malaya campus. They were brought back to the laboratory and kept in screened plastic aquaria with suitable substrate for the larvae to develop and pupate [5, 6]. Pupae were collected and placed in small plastic tubes for development. Emerging adult fruit flies were collected and identified. Parasitoids that emerged were also recorded.

RESULTS

During late December 2013 and early January 2014, female *B. tau* was seen ovipositing on ripe fruit of *T. wallichiana* (Fig. 1) in the garden of Institute of Biological Sciences, University of Malaya. Multiple females at times oviposited together at the same spot (putrefied area) of the fruit.

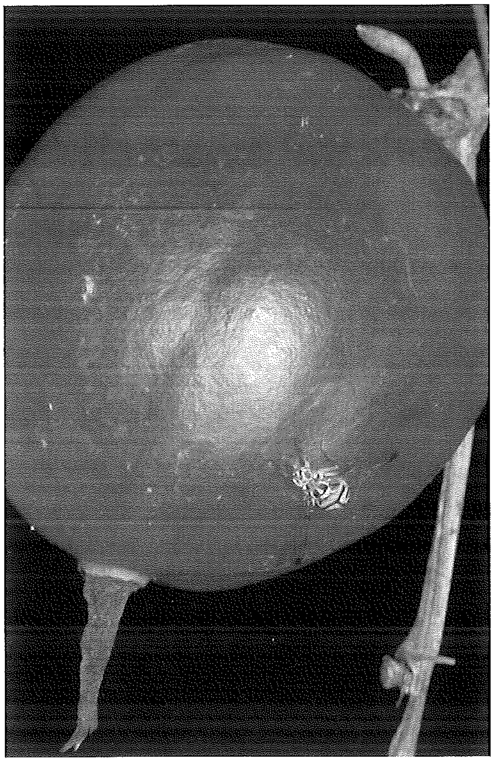

Figure 1. Female *Bactrocera tau* ovipositing on fruit of *Trichosanthes wallichiana*.

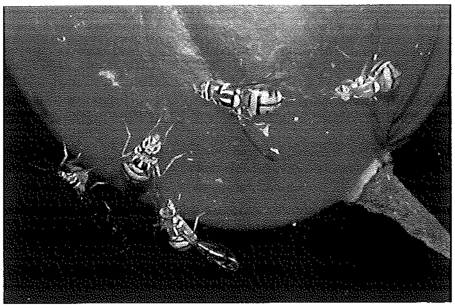

Figure 2. Female *Bactrocera tau* (centre and left) and *Bactrocera cucurbitae* (right) on fruit of *Trichosanthes wallichiana*.

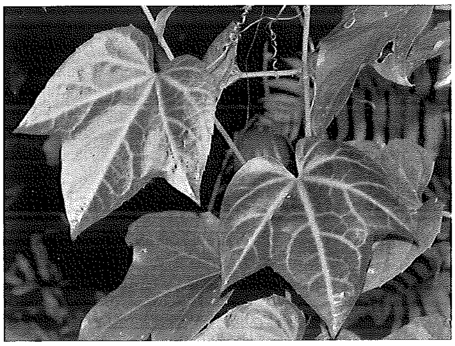

Figure 3. *Trichosanthes wallichiana*.

Occasionally, female *Bactrocera cucurbitae* was seen 'ovipositing' on the fruit together with *B. tau* (Fig. 2).

From the fruit collected end December 2013, more male *B. tau* flies were recovered – 52 males and 37 females; the ratio was not significantly different, $\chi^2 = 2.52$, $0.1 > P > 0.05$. The pupation period was 9–10 days. In a small number of pupae kept individually, the mortality was 2/11 (18.18%). No *B. cucurbitae* and parasitoids were recovered.

DISCUSSION

Trichisanthes wallichiana (Crow's Cucumber) is a climber (Fig. 3) growing in forest edge and open places in the lowlands [7]. It is a member of the Cucurbitaceae. The roundish fruit measures 5 to 10 cm long, and when ripe is red in colour (Fig. 1). It has a hard outer rind. The seeds are embedded in greenish-black pulp.

The genus *Trichosanthes* has been recorded as host of various tephritid fruit flies [2] – *T. cucumerina*: possible or likely host of *B. tau* and *B. caudata*, doubtful host of *B. latifrons*, and host of *B. cucumis*, *B. cucurbitae*, *Dacus axanus*, *D. eumenoides*, *D. petioliforma*, *D. demmerezi*, and *D. ciliatus*; *T. cucumeroides*: host of *B. scutellata*; and *T. dioica*: possible or likely host of *B. cucurbitae*. More recently, *T. tricuspidata* [4] and *T. dioica* [8] have been reported as host of *B. tau*.

As far as known, *Trichosnathes* has not been reported as host of tephritid fruit flies in Malaysia. In the present study, *B. tau* was observed ovipositing on ripe fruit of *T. wallichiana*, and more male flies were recovered compared to female flies. In flies recovered from *M. charantia* (bitter gourd) from the same locality (unpublished data), there were also more males than females (10 ♂♂ : 6 ♀♀; $\chi^2 = 1.0$, $P > 0.3$).

The present finding adds a new species to the list of host plants of tephritid fruit flies in general, and *B. tau* in particular. It is a new genus of host plant for Malaysia. As *B. cucurbitae* was observed on the fruit, *T. wallichiana* may also be a likely host of this fruit fly.

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Oyster culture in Malaysia: Opportunities and challenges

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Abstract Oysters are known to be consumed by the coastal communities for centuries and sold in very small scale in the local markets. However, compared to other bivalve molluscs, oysters are relatively unknown in Malaysia due to low production and lack of publicity. The Malaysian Government had tried to promote oyster farming among the local coastal communities with the support from international agencies and the Department of Fisheries Malaysia, together with local institutions since the late 1980s. The expansion of oyster culture industry in Malaysia could be much faster if not because of limited seed supply. Many studies have been conducted on the biology, growth and production of oysters but, little has been reported on the challenges and opportunities of oyster culture in Malaysia. The linkages between farmers, research/ technology development and extension will be addressed in this paper.

Keywords aquaculture – edible oyster – production

INTRODUCTION

With Vision 2020, the standard of living in Malaysia is rising year by year, and this has been accompanied by increased consumption of luxury seafood. Half shell oysters are served in the finest seafood restaurants and hotels of the country (Nair *et al.*, 1993). There are two Malaysian species, which are suitable for the half shell trade. The Department of Fisheries Malaysia conducted several promotion campaigns from 1993 to 1994 to promote local oysters with collaboration with leading hotels and restaurants (Devakie *et al.*, 1993). The response had been overwhelming and generated more demand than the numbers of farmers were able to supply (Mohamad Yatim, 1993).

Under the auspices of the Bay of Bengal Programme (1988–1993), the Department of Fisheries Malaysia undertook the introduction of oysters farming in Kedah, Perak, Langkawi, Johor, Kelantan and Terengganu. Not much attention was given to Sabah and Sarawak during that time. Expansion of oyster farming industry in Malaysia could be much faster if not because of limited seed supply (Nair *et al.*, 1993; Wong, 1990). Only hatchery production can provide the required supply of seed both in term of quantity and quality, for the expansion of the farming industry.

The current status of oyster culture as stated in this paper is based on personal knowledge, combined with findings of a review of the subject recently done by the Department of Fisheries (DOF) Malaysia in consultation with a variety of local farmers and oyster suppliers.

TRADITIONAL CULTURE

Oysters have been traditionally harvested as seafood in Malaysia. *Crassostrea iredalei*, *Crassostrea belcheri* and *Saccostrea cucullata* have been collected by local fishermen for several decades from intertidal rocks, estuarine river bottom, jetties and fishing stakes in coastal areas and islands throughout Malaysia. The locals were only able to harvest the wild oysters for a few hours when the tide was out. The oysters harvested were mainly in fresh form or as shucked meat for local consumption, sold in the local markets. The contribution of traditional oyster supply to overall production in Malaysia is not well documented. The fresh oysters sold in 5-star hotels and luxury seafood restaurants were mainly imported oysters.

COMMERCIAL SPECIES

There are two commercial species cultured and marketed in Malaysia, namely the Slipper oyster *Crassostrea iredalei* and tropical oyster *Crassostrea belcheri* (Devakie and Ali, 2000; Najiah *et al.*, 2008). These species are harvested mainly to be sold as fresh live oysters in hotels and restaurants. The rock oyster *Saccostrea cucullata* is mainly harvested from the intertidal areas during low tides and sold as shucked meat at the local markets (Markid, 2002; Szuster *et al.*, 2008; Tan, 2001).

OYSTER CULTURE AND PRODUCTION

Oyster production in Malaysia had increased over the past 10 years. The highest production was recorded in year 2009 (Fig. 1), but seems to be stagnant lately (year 2011–2013) (Department of Fisheries, 2013). The oyster industry in Malaysia is not able to take off fully due to several constraints such as insufficient seed supply and limited culture sites. These constraints will be discussed further in the later section (under *Challenges*).

Figure 2 shows the oyster culture areas in Malaysia for year 2013. Sabah contributed 98% of the total oyster production and 97% of the total wholesale value. Sabah has also the most number of oyster culturists (344) compared to the number of culturists in Peninsular Malaysia (DOF, 2013). The high number

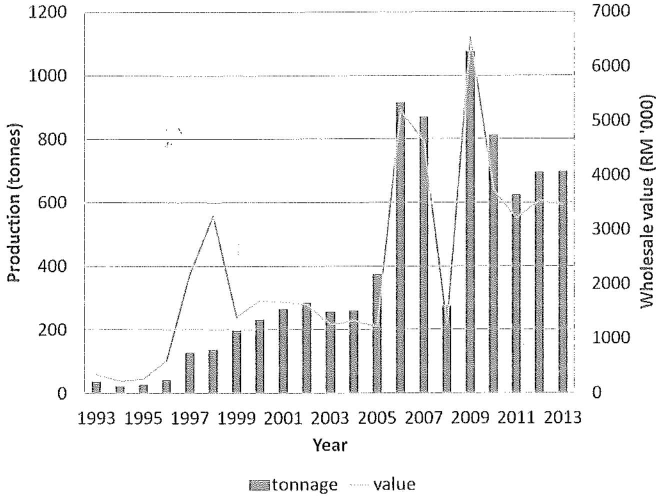

Figure 1. Oyster production and wholesale value of oysters in Malaysia from 1993–2013 (source from Annual Statistics of Department of Fisheries Malaysia, DOF, 2013).

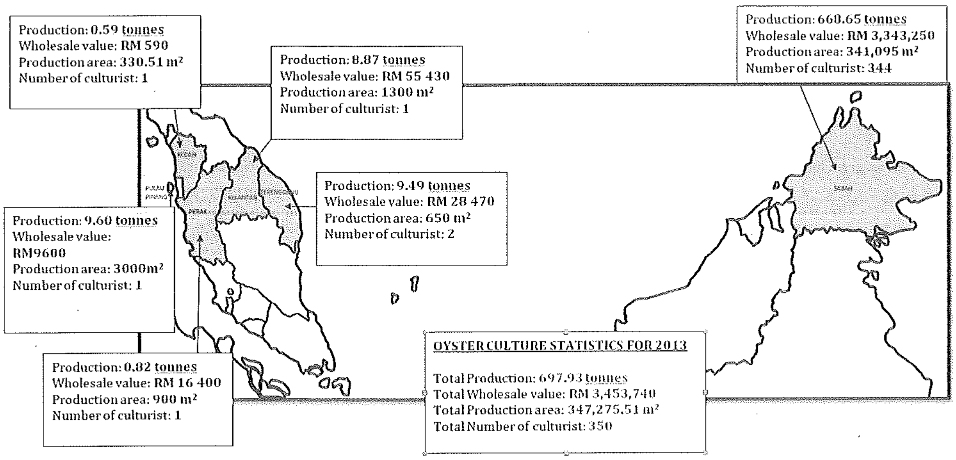

Figure 2. The oyster culture sites and statistics on production in year 2013 (adapted from Department of Fisheries Malaysia Annual Fisheries Statistics 2013).

of oysters recorded in Sabah is actually based on pearl oyster culture, instead of the edible oyster culture as recorded in Peninsular Malaysia. The rise in number of oyster culturists in Sabah started in the late 1990's where pearl oyster farming started to gain popularity (DOF, 2013). Due to its profitable nature where a single pearl could fetch up to a few thousand Ringgit as seawater pearl oyster takes about four to six years to grow before harvesting, it is no wonder that new culturists followed suit in this high risk but high profit industry. Due to the high costs and time invested in nurturing the pearls, no part of this oyster is wasted. According to Chin (2008), Malaysia's most successful pearl oyster farmer, the pearl oyster meat is exported to Hong Kong and sold there for about RM1440 per kilogramme. Pearl oyster farming continued to rise since then, overtaking Peninsular Malaysia's oyster farming production. In Year 2012, the Kota Marudu Parliamentary Agriculture Development Council approved of an oyster farming project involving 10 pioneering fishermen in collaboration with the Sabah Fisheries Department and a private company utilizing Taiwanese technology as it was deemed economically viable in the Marudu Bay waters (New Sabah Times, 2012).

Table 1 shows the total production, wholesale value, culture areas and number of culturists from year 2005 till 2013. There was a sharp increase in total production and wholesale value of oysters in year 2009, where the number of culturists was high. Following that year, the total production had dropped and become stagnant over the next few years. The number of culturists had also gradually dropped over these years.

OYSTER CULTURE RESEARCH

The first attempt to culture oysters was in the 1960s (Okada, 1963). In the 1970s, culture of *C. belcheri* was carried out in Sg. Mapang, Tawau, Sabah (Chin and Lim, 1975) and *C. iredalei* in the coastal areas of Peninsular Malaysia. During that time, the Fisheries Research Institute (FRI), Department of Fisheries, Malaysia (DOF), had successfully demonstrated the culture of the flat oyster, *Ostrea folium,* in the intertidal area of Pulau Langkawi, Kedah (Ng, 1979). The Government of Malaysia had targeted oysters for aquaculture development in its 7th Five-Year Plan.

In 1988, the Department of Fisheries received technical and financial support from the Bay of Bengal Programme (BOBP) under a programme entitled "Oyster

Table 1. Total production, wholesale value, culture area and number of culturists from year 2005 till 2013 (source : Department of Fisheries Malaysia Fisheries Statistics, 2013).

Year	Total production (tonnes)	Wholesale value (RM '000)	Culture area (m2)	Number of culturist
2005	373.72	1218.88	310,963.78	433
2006	915.56	5189.88	326,903.40	490
2007	869.72	4615.86	398,208.33	509
2008	275.47	1253.22	272,102.49	459
2009	1075.15	6540.63	337,461.67	422
2010	812.76	3730.83	364,908.08	459
2011	625.89	3206.77	127,718.00	262
2012	695.20	3533.86	356,700.51	459
2013	697.93	3453.74	347,275.51	350

Culture in Malaysia". This programme was later co-supported by the International Development & Research Canada (IDRC) to study the biology and culture of oysters in the tropics. The other neighbouring countries that were also involved under these two programmes were Indonesia, Thailand and the Philippines.

Under the BOBP's support, sites were selected and local participants were identified with the assistance from the Fisheries Research Institute, Penang. Site selection was conducted in the west coast of Peninsular Malaysia and then extended to the east coast of Peninsular Malaysia, highly depending on sites which were able to obtain oyster seeds from the wild. Local participants were taught on spat collection and selection of cultch materials for seed collection. Over the years, BOBP's support was limited to spat collection and site selection.

The research supported by IDRC and Malaysian Government was more focused on the breeding biology and artificial spawning of oysters. Hatchery seed production and remote setting were done by biologists and staff of the Fisheries Research Institute and Universiti Sains Malaysia. Artificial spat production was necessary to supplement short supplies of wild spat.

The recent research is focused on the improvement of meat quality, growth, hybridization, advanced hatchery technologies and marketing. The Malaysian Government had been supporting research on oysters to enhance food security, through the Ministry of Science Technology and Innovation and Ministry of Agriculture. Some funding support has been awarded by private agencies, such as The Malaysia Toray Science Foundation.

CHALLENGES

Most of the oyster seeds used for farming in Malaysia was harvested from the wild and currently Malaysia is facing serious problems in sustaining the industry due to insufficient seed stock. There was a stage that Malaysia was importing natural seeds from Thailand and Myanmar, and now facing difficulties in obtaining natural seeds from these countries. The expansion of oyster farming industry in Malaysia could be much faster if not because of limited seed supply. Only hatchery production can provide the required supply of seed both in term of quantity and quality, for the expansion of the farming industry.

The research on oyster seed production had been initiated in Malaysia since 1989 under the programme by IDRC and the 5^{th} and 6^{th} Malaysian Plan. The first pilot hatchery for oyster seed production had been successfully set-up in 2009. This may be the only two commercial oyster hatcheries in ASEAN, with the other hatchery located in Vietnam. With the availability of hatchery-produced oyster seeds, oyster farming is blooming in the coastal areas of Malaysia.

Oyster culture in Malaysia is currently in its infant stage and still a lot more need to be done to improve the quality and quantity for local consumption as well as for export market. However, oysters cultured at several sites in Malaysia experience low quality meat after spawning and making the product undesirable (Tan *et al.,* 2014). Therefore, triploid oysters were introduced, where sterile triploids do not spawn during the spawning season and the meat quality remains good throughout the year.

Triploidy technology had been used by some small-scale hatcheries but was found undesirable because the induction of triploids could never be 100% due to high mortality rate and the chemicals used are hazardous. Therefore, scientists are currently looking into the technology of producing tetraploids, which is able to produce 100% triploids when the tetraploid oysters are crossed with the diploid oysters.

Besides the meat quality of the oysters, the expansion of oyster culture has been hindered by limited awareness of its nutritional values. Most people consider oysters contain high cholesterol levels since it has been categorized under "shellfish" which contains high cholesterol, similar to prawns and crabs. Most people are not aware that consuming a dozen of oysters is equivalent to a quarter of an egg yolk (USDA). Doctors in developed countries have recommended their heart patients to consume oysters as an alternative for protein source.

Diseases and mass mortalities

In spite of great importance of mollusks in the tropics, there is no publication on tropical mollusk diseases so far. The occurrence of mollusk diseases often differs with the temperate and tropical waters. Elston (1990) and Sindermann (1970), the parasite known as *Perkinsus marinus* or Dermo that mostly infected on oyster tissues and caused oyster mortality. However, most of the reports are on temperate oyster species. There are many examples of the severe impact of disease outbreaks and mass mortality, which are increasingly recognized as a significant constraint to aquaculture production and trade. Lately, oyster growers in Sabah are experiencing mass mortality in their culture and yet to detect the cause of the mortality. Based on the study by Erazo-Pagador (2010), digenetic trematodes (*Nemaptosis* sp.) were found in slipper oyster, *Crassostrea iredalei*. However, no in-depth study had been conducted on the diseases of oysters in the tropics. Therefore, it is important to have research focusing on the major diseases of tropical mollusks along with their geographic distribution, pathology, diagnostic techniques as well as currently practiced prevention and control measures.

Hybridization and selective breeding

In other efforts to improve performance of oyster, hybridization of two inbred families such as the Pacific oyster (*Crassostrea gigas*) and the Hong Kong oyster (*Crassostrea hongkongensis*) has been carried out to adapt towards high salinity and heat stress in the hybrid while maintaining its large size which is sought after in the market (Zhang *et al.*, 2012). In our region, hybridization of *Crassostrea iredalei* and *Crassostrea belcheri* has been successfully carried out (Kyra, 2012) by the Fisheries Research Institute in Malaysia and undergoing studies for growth rate determination and other sensory studies. The hybrid theoretically will have bigger size like *C. belcheri* and taste profile of *C. iredalei.*

Processing and marketing

Research and development programmes had been focused on the biology and reproduction of oysters, leading to very little attention towards the processing and marketing issues faced especially by the small scale growers.

Ocean acidification

Most of the ocean acidification impacts are gradual and long term and may eventually lead to changes in ecosystems of future oceans (IPCC, 2007). The decrease in pH had caused difficulties for marine calcifying organisms to form biogenic calcium carbonate ($CaCO_3$), besides dissolving rapidly the existing $CaCO_3$ (Doney *et al.*, 2009; Rodolfo-Metalpa *et al.*, 2010). It is still unclear if the ecosystems have the ability to adapt to these changes. Oysters cultured at sites subjected to huge amount of rainwater runoff from rivers would be exposed to lower pH values. The shells of these oysters are thinner and they are more prone to be attacked by predators like crabs or fish. This will eventually lead to higher mortality and lower productivity.

OPPORTUNITIES

Despite high risks and investment costs, high and increasing demand and market value of oysters are encouraging. If social and environmental sustainability issues can be successfully addressed, increasing market demand and higher prices should open opportunities for a range of growers and investors. Increasing productivity of both large and small-scale oyster farms will require major investments in research, development and extension as well as policy shifts.

Oyster farming is a newly emerging seafood industry in Malaysia. It has enormous potential for growth, in both local and international market. The current oyster trade in Malaysia is valued at RM28 million (Malaysia's Trade Statistics) in 2013. This represents only 14% of the demand (Fig. 3). The demand is imposed by the limitation in oyster seed supply and long culture cycles. Currently, oyster farming can rely on hatchery-produced seeds instead of the natural seeds, which are inconsistant in amount and seasonal (Nair *et al.*, 1993; Wong, 1990). Therefore, the oyster industry in Malaysia should be able to take off with transfer of the oyster farming technology to the local communities or growers.

Oyster farming is a clean aquaculture whereby no feed will be required for the

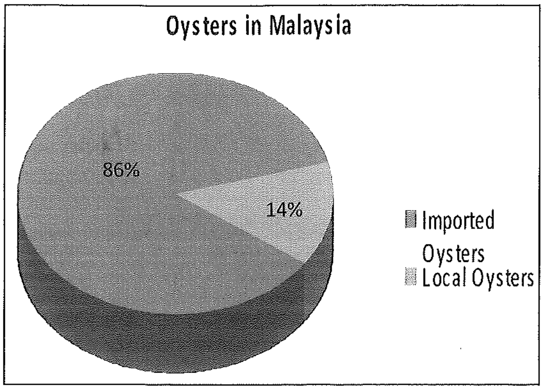

Figure 3. Oyster trade in Malaysia in year 2013.

oysters to grow. The oysters will only rely on the natural food i.e. phytoplankton. Basically, it is a very simple aquaculture that can be adapted by the local society in the selected area. The major labour, once the floats are built and the oysters are growing, is periodic agitation at the beginning (about once a week, to prevent seed oysters from fusing to one another) and removing algae and other fouling organisms, which can restrict the flow of water and food organisms into the floats and compromise growth and survival.

Oyster farming requires low technology, which can be applied by almost all fishermen. Since it requires low technology and low labour, this aquaculture can be done on a part-time basis (e.g. local community can still involve in their daily activities i.e. fishing or farming in the morning and handle the oyster culture in the afternoon). Therefore, oyster farming will be able to generate additional income for the local community once the oysters reached marketable size (between 8 to 10 months, depending on the site selected). If each fisherman will be able to sell approximately 2,000 oysters per month at a minimum of RM0.80 per piece, they can generate an additional RM1,600 per month on a part-time basis. The profit will still be attractive even they have to consider the cost of petrol and cost of seeds (seeds need to be continuously purchased for sustainability).

Currently, the *First Commercial Oyster Hatchery* (awarded by the Malaysia Book of Records in 2014) had been setup in Malaysia. This is not only the first commercial oyster hatchery in Malaysia but also the first in the region, which is an achievement that Malaysians should be proud of. Hecht (2000) recommended that aquaculture funding, which targeted the 'poorest to the poor' had been proposed to the small scale entrepreneurs in this sector to increase productivity. The Malaysian Government is now moving towards helping the local communities by introducing oyster culture as an alternative livelihood by bridging the gap between the industry and communities. Oyster farming is an ideal choice for alternative livelihood for local coastal communities since it is considered a green aquaculture, where no feed or antibiotics are required for the farming. The coastal local communities involved currently are situated in Kedah, Perak, Selangor and Johor. Now, Malaysia is able to produce our very own fresh oysters to be consumed locally as well as internationally.

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Large amplitude solitary waves in a four-component dusty plasma with vortex-like (trapped) electron distributions

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Abstract Nonlinear dust acoustic solitary waves are studied in a four-component dusty plasma with vortexlike electron distribution. The modified Korteweg-de Vries (mKdV) equation is derived by Reductive perturbation technique (RPT). A non-linear pseudo-potential technique is also employed to investigate the large amplitude solitary waves with the effects of vortex like electron in the plasma system. The existence of large amplitude positive and negative solitary waves is found. It is seen that solitons cease to exist when the parameter b (measures the deviation from iso-thermality) crosses a certain value. If b is less unity and ψ (pseudo-position) increases then pseudo-potential increases very sharply from negative to positive potential value.

Keywords Dusty Plasma – Plasma Waves –Soliton-Vortex

INTRODUCTION

Dusty plasma research becomes widely appreciated as it plays important role in space plasma, astrophysical plasma, laboratory plasma and environment. Presence of dust in plasma has been found in cometary tails, asteroid zones,planetary ring, interstellar medium, lower part of earth's ionosphere and magnetosphere [1-8], radio frequency plasmadischarge [9], coating and etching of thin films [10] and in plasma crystal [11]. Many authors have been investigatedthe nonlinear structures like solitons, shocks and vortices in such plasmas [12-24]. Bliokh *et al.*[14] first theoreticallypredicted such waves while dealing with waves in Saturn's ring. Later, nonlinear wave phenomena in dusty plasmain several new eigen modes like as dust-acoustic wave (DAW) [15, 16], dust ion-acoustic wave (DIAW) [17, 18] andDust Lattice (DL) waves [19, 20], Dust-Berstain-Greene-Kruskal (DBGK) mode [21, 22], Shukla-Verma mode [23], Dust-drift mode [24] etc are studied extensively. Dusty plasma supports mainly two types of acoustic waves: highfrequency DIAW involving mobile ions and static dust grains, and a low frequency DAW involving mobile dust grains.Both of these modes have been studied theoretically [25-29] and experimentally [30, 31]. However, in most of the theoretical works the plasma is considered as three-component dusty plasma system consisting of ions, electrons and negatively charged dust particles. But positively charged dust grains are also present in different areas of space plasma [32-34]. Fortev *et al.* [35] explained the mechanism by which a dust grain can be positively charged. Chow *et al.* [34] also explained the situations under which smaller dust particles become positively charged and larger particles become negatively charged. It is also found that both positively and negatively charged dust exist simultaneously in different space plasmas [27-29, 34, 35].

Recently, few works have been done to understand the behavior of solitary structures in such environment. Sayed and Mamun [36] investigated the solitary waves in a four component dusty plasmas where they considered both positively and negatively charged dust particles. Using Reductive perturbative approach they have mentioned that small but finite amplitude solitary potential structures may exist in such a four-component dusty plasma. They have also found that the presence of additional positive dust component can significantly modify the basic properties of solitary potential structures in a dusty plasma. Later on Chatterjee and Kundu [37] extended the work of Sayed and Mamun [36] to study the arbitrary amplitude of solitary waves by using Sagdeev's pseudo potential approach [38]. Chatterjee and Roy [39] investigated the large amplitude solitary waves with the presence of non-thermal ions. Recently Roy *et al.* [40] studied the effect of kappa distributed electrons on arbitrary amplitude double layers in afour-component dusty plasma. Mandal *et al.* [41] also studied the large amplitude double layers in a four-componentdusty plasma with non-thermal electrons.

However, till today a few number of works has been done to study the behavior of solitary structures of four componentdusty plasma where electrons are considered as non-isothermal which are present in different space environments. Here in our present model we consider the vortex like distribution of non-isothermal electrons as introduced by Schamel [42, 43]. If streaming particles are injected in a plasma, it is found that they evolve towards a coherent trappedparticle state and it has also been confirmed in experiments [44]. Electron trapping is found in the formation of double layers [45, 46] and in some other simulations [47, 48]. Also Mamun and Shula [27] have studied the electronacoustic solitary waves with vortex like electron distribution. For large amplitude nonlinear waves, some electrons are assumed to be trapped in the electrostatic potential and carried along with the wave. As electron trapping is a nonlinear phenomenon, so it is obvious that electron trapping must exists in nonlinear wave phenomena. Hence, trapped electrons are indispensable to understand nonlinear waves. However, very few theoretical investigations have been done by considering trapped electrons as one of the constituents of dusty plasma. Hence, in this present work weare interested to investigate the effects of trapped electrons extensively in nonlinear wave phenomena.

The organization of this paper is as follows. In part II we present the basic equations for a four-component dusty plasma and mKdV equation is derived using RPT. In part III Sagdeev's pseudo-potential is derived. Different conditions for the existence of large amplitude solitary waves are also discussed in this part. In part IV results and discussions are shown, and finally the last part V for conclusion.

BASIC EQUATIONS AND RPT APPROACH

To study the effects of non-isothermal electrons on the nonlinear ion-acoustic waves, vortex-like electron distribution function of Schamel [45, 46] is employed. The functions are as follow:

$$f_{ef} = \frac{1}{\sqrt{2\pi}}\exp\left[\frac{(v^2-2\psi)}{2}\right], |v| > \sqrt{2\psi}, \quad (1)$$

$$f_{et} = \frac{1}{\sqrt{2\pi}}\exp\left[-\frac{\beta_1(v^2-2\psi)}{2}\right], |v| < \sqrt{2\psi} \quad (2)$$

where the subscript ef (et) represents the free (trapped) electron contribution. The distribution functions written in eqs. (1) and (2) are continuous in velocity space and satisfy the regularity requirements for an admissible Bernstein-Green-Kruskal (BGK) solution. The velocity is normalized by the electron thermal velocity. β_1 is a parameter that determines the number of trapped electrons, whose magnitude is defined by the ratio of free electron temperature (T_{ef}) and trapped electron temperature (T_{et}). It has been assumed that the velocity of nonlinear ion acoustic wave is small in comparison with the electron thermal velocity. Integrating the electron distribution function over the velocity space, we readily obtain the electron number density n_e as

$$n_e = e^{\psi} erfc(\sqrt{\psi}) + \frac{e^{\beta_1\psi}}{\sqrt{|\beta_1|}} erf(\sqrt{\beta_1\psi}) \quad (\beta_1>0), \quad (3)$$

$$n_e = e^{\psi} erfc(\sqrt{\psi}) + \frac{2}{\sqrt{\pi|\beta_1|}} W(\sqrt{-\beta_1\psi}) \quad (\beta_1<0) \quad (4)$$

where W is Dawson integral and $erfc(\psi) = 1 - erf(\psi)$ is the complementary error function. If we expend n_e for the small amplitude limit and keep the terms up to ψ^2 it is found that n_e is same for both $\beta_1 > 0$ and $\beta_1 < 0$, and finally we have

$$n_e = 1 + \psi - \frac{4}{3} b\psi^{3/2} + \frac{1}{2}\psi^2 \quad (5)$$

where $b = (1-\beta_1)\pi^{1/2}$ measures the deviation from iso-thermality. The term b>0 is the contribution of the resonant electrons to the electron density.

We consider a four-component dusty plasma consisting of Boltzmann distributed ions and non-isothermal electrons, and negatively and positively charged dust grains. The basic equations are as follow:

$$\frac{dn_1}{dt} + \frac{d(n_1 u_1)}{dx} = 0, \quad (6)$$

$$\frac{\partial u_1}{\partial t} + u_1 \frac{\partial u_1}{\partial x} = \frac{\partial \psi}{\partial x}, \quad (7)$$

$$\frac{dn_2}{dt} + \frac{d(n_2 u_2)}{dx} = 0, \quad (8)$$

$$\frac{\partial u_2}{\partial t} + u_2 \frac{\partial u_2}{\partial x} = -\alpha\beta \frac{\partial \psi}{\partial x}, \quad (9)$$

$$\frac{\partial^2 \psi}{\partial x^2} = n_1 - (1 - \mu_i + \mu_e) n_2 - \mu_i e^{-\sigma\phi} + \mu_e n_e. \quad (10)$$

where n_1 and n_2 are the negative and positive dust number densities normalized by the values n_{10} and n_{20} respectively, u_1 and u_2 are negative and positive dust filed speed normalized by $C_1 = \sqrt{Z_1 k_B T_i / m_1}$; ϕ, the electric potential is normalized by $k_B T_i / e$; x and t are normalized by $\lambda_D = \sqrt{k_B T_i / 4\pi Z_1 e^2 n_{10}}$ and $\omega_{p1}^{-1} = \sqrt{m_1 / 4\pi Z^2{}_1 e^2 n_{10}}$. $\alpha = Z_2 / Z_1$, $\beta = m_1 / m_2$, $\mu_e = n_{e0} / Z_1 n_{10}$, $\mu_i = n_{i0} / Z_1 n_{10}$, $\sigma = T_i / T_e$, Z_1 and Z_2 are the number of electrons or protons residing on a negative and positive dust particle respectively. m_1 and m_2 are the mass of the negative and positive dust particles respectively. T_i and T_e are ion and electron temperatures respectively, k_B is the Boltzmann constant and e is the charge of the electron.

Now, we derive the mKdV from equations (6)-(10) by employing the reductive perturbation technique. The independent variables are stretched and the dependent variables are expanded as $\xi = \varepsilon^{1/4}(x - v_0 t)$, $\tau = \varepsilon^{3/4} t$ and the dependent variables are expanded as

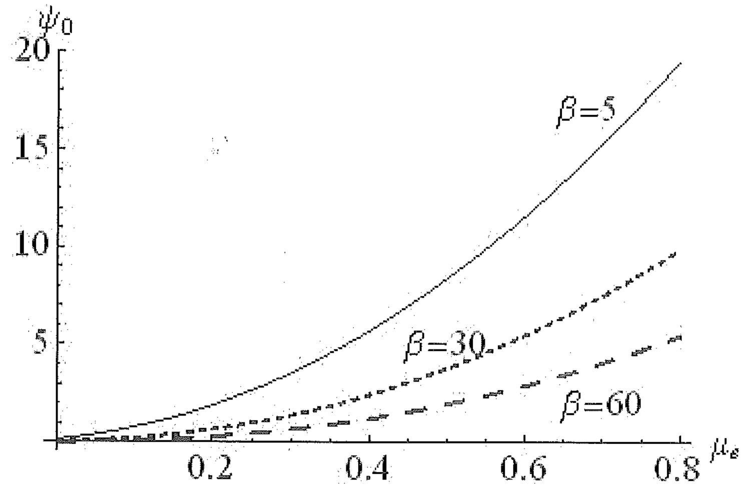

Figure 1. The variation of the amplitude ψ_0 of positive solitary waves against μ_e for different β with $\alpha = 0.01$, $\sigma = 0.5$, $\mu_i = 0.2$, $b = 0.35$

$$n_1 = 1 + \varepsilon n_1^{(1)} + \varepsilon^2 n_1^{(2)} + \varepsilon^3 n_1^{(3)} + \ldots, \tag{11}$$

$$n_2 = 1 + \varepsilon n_2^{(1)} + \varepsilon^2 n_2^{(2)} + \varepsilon^3 n_2^{(3)} + \ldots, \tag{12}$$

$$u_1 = 0 + \varepsilon u_1^{(1)} + \varepsilon^2 u_1^{(2)} + \varepsilon^3 u_1^{(3)} + \ldots, \tag{13}$$

$$u_2 = 0 + \varepsilon u_2^{(1)} + \varepsilon^2 u_2^{(2)} + \varepsilon^3 u_2^{(3)} + \ldots, \tag{14}$$

$$\psi = 0 + \varepsilon \psi^{(1)} + \varepsilon^2 \psi^{(2)} + \varepsilon^3 \psi^{(3)} + \ldots \tag{15}$$

where ε is a small non-zero parameter proportional to the amplitude of the perturbation. Now, substituting (11)-(15) into (6)-(10) and taking the terms in different power of ε. We obtain the dispersion relation for the lowest order of ε as

$$V_0^2 = \frac{1 + \alpha\beta(1 + \mu_e - \mu_i)}{\sigma\mu_i + \mu_e} \tag{16}$$

In the next higher order of ε, we eliminate the second order perturbed quantities from a set of equations to obtain the required mKdV equation.

$$\frac{\partial \psi^{(1)}}{\partial \tau} + A\sqrt{\psi^{(1)}}\frac{\partial \psi^{(1)}}{\partial \xi} + B\frac{\partial^3 \psi^{(1)}}{\partial \xi^3} = 0 \tag{17}$$

where the nonlinear coefficient A and the dispersion coefficient B are given by

$$A = \frac{bV_0}{\mu_i\sigma + \mu_e}, \tag{18}$$

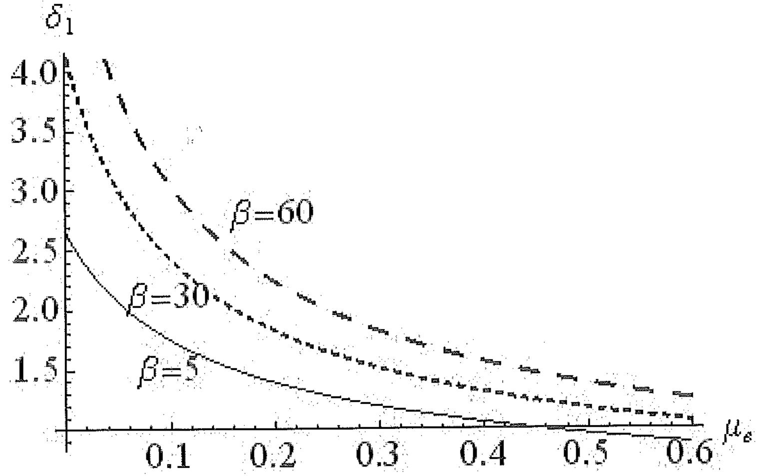

Figure 2. The variation of the width δ_1 of positive solitary waves against μ_e for different β with $\alpha = 0.01$, $\sigma = 0.5$, $\mu_i = 0.2$, $b = 0.35$

$$B = \frac{V_0}{2(\mu_i\sigma + \mu_e)} \tag{19}$$

In order to derive the stationary solution of mKdV equation(17), we introduce a new coordinate $\eta = \xi - U\tau$ with respect to a frame moving with the velocity U and use the boundary conditions viz., $\psi^{(1)} \to 0,\ \partial\psi^{(1)}/\partial\eta \to 0,\ \partial^2\psi^{(1)}/\partial\eta^2 \to 0$ at $\eta \to \pm\infty$. Thus, one can express the steady state solution of the mKdV equation as

$$\psi^{(1)} = \psi_0 \sec h^4(\eta/4\delta_1) \tag{20}$$

where $\psi_0 = 225U^2/64A^2$ and $\delta_1 = \sqrt{B/U}$ represent the amplitude and width of the solitary waves, respectively.

PSEUDO-POTENTIAL APPROACH

In order to search for solitary waves from equations (6)-(10), we introduce a linear substitution $\xi = x - Mt$ admitting only solutions which depend on space and time in the form of the wavy variable $x - Mt$. By substitution $\frac{\partial}{\partial x} = \frac{d}{dx}$ and $\frac{\partial}{\partial t} = -M\frac{d}{d\xi}$ (6)-(10) reduce to

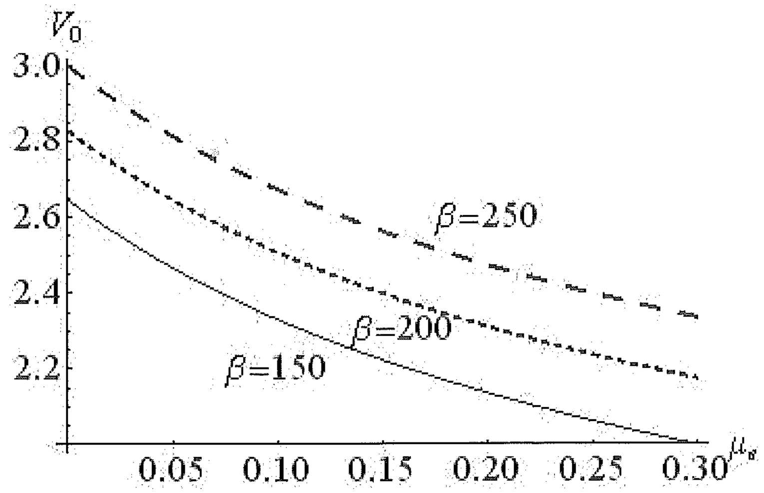

Figure 3. The variation of the Mach number V_0 of positive solitary waves against μ_e for different β with $\alpha = 0.01$, $\sigma = 0.5$, $\mu_i = 0.2$, $b = 0.35$

$$-M\frac{dn_1}{d\xi}+\frac{d(n_1u_1)}{d\xi}=0, \tag{21}$$

$$-M\frac{du_1}{d\xi}+u_1\frac{du_1}{d\xi}=\frac{d\psi}{d\xi}, \tag{22}$$

$$-M\frac{dn_2}{d\xi}+\frac{d(n_2u_2)}{d\xi}=0, \tag{23}$$

$$-M\frac{dU_2}{d\xi}+u_2\frac{du_2}{d\xi}=-\alpha\beta\frac{d\psi}{d\xi}, \tag{24}$$

$$\frac{d^2\psi}{d\xi^2}=n_1-(1-\mu_i+\mu_e)n_2+\mu_e n_e-\mu_i e^{-\sigma\psi}. \tag{25}$$

The boundary conditions are: ψ, u_1, $u_2 \to 0$, $n_1, n_2 \to 1$, $n_i \to \mu_i$, $n_e \to \mu_e$ as $|\xi| \to \infty$. From (21) we get

$$n_1=\frac{M}{M-u_1}. \tag{26}$$

Similarly from (23) we get

$$n_2=\frac{M}{M-u_2}. \tag{27}$$

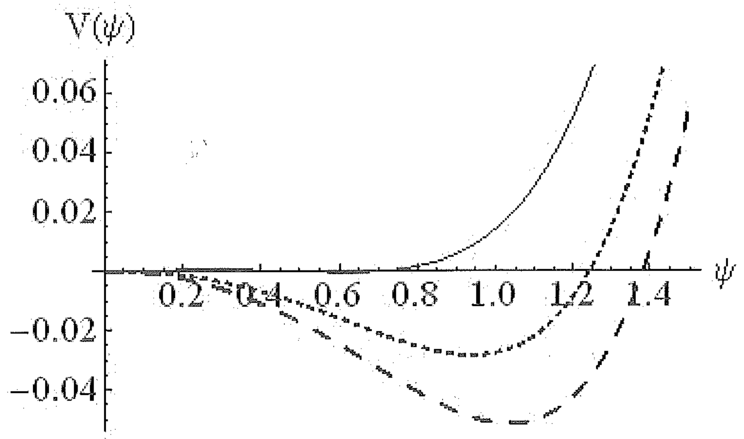

Figure 4. The variation of the potential $V(\psi)$ of the solitary waves against ψ for different values of M, the soliton velocity i. e., M = 1.25 (solid line), M = 1.85 (dotted line) and M = 12.0(dashed line), where $\alpha = 0.01$, $\sigma = 0.5$, β=50, $\mu_i = 0.2$, $b = 0.35$.

From (22) we get

$$\psi = -Mu_1 + \frac{u^2_1}{2}. \tag{28}$$

And from (24) we get

$$\alpha\beta\psi = Mu_2 - \frac{u^2_2}{2}. \tag{29}$$

Now using (26)-(29) in (25) we get

$$\frac{d^2\psi}{d\xi^2} = -\frac{\partial V(\psi)}{\partial\psi}, \tag{30}$$

$$V(\psi) = M^2\left[1-\left(1+\frac{2\psi}{M^2}\right)^{1/2}\right] + \frac{M^2}{\alpha\beta}(1-\mu_i+\mu_e)\left[1-\left(1-\frac{2\alpha\beta\psi}{M^2}\right)^{1/2}\right] + \frac{\mu_i}{\sigma}(1-e^{-\sigma\psi}) - \mu_e\left[\psi+\frac{\psi^2}{2}-\frac{8}{15}b\psi^{5/2}+\frac{\psi^3}{6}\right] \tag{31}$$

Multiplying both sides of (30) by $2\frac{d\psi}{d\xi}$ and integrating w. r. to ξ with the boundary conditions $|\xi| \to \infty$, $V \to 0$ and $\frac{d\psi}{d\xi} \to 0$, we get

$$V(\psi)+\frac{1}{2}\left(\frac{d\psi}{d\xi}\right)^2=0 \qquad (32)$$

Equation (32) can be considered as a motion of a particle (whose pseudo-position is ξ) with pseudo-velocity $d\psi/d\xi$ in a pseudo-potential well $V(\psi)$. That is why Sagdeev's potential is called pseudo-potential. Hence the conditions for the existence of solitary wave solutions are:

(i) $V(\psi)$ has a double root at $\psi=0$. Moreover $V(\psi)$ has a local maximum at $\psi=0$, i. e. $dV/d\psi$=0 at $\psi=0$ and $d^2V/d\psi^2<0$ at ψ=0.

(ii) There exists a nonzero ψ_m, the maximum(or minimum) value of ψ, where $V(\psi_m)=0$. ψ_m is the amplitude of the solitary wave. If ψ_m is positive then the solitary wave is called compressive solitary wave, and if ψ_m is negative then the solitary wave is called rarefractive solitary wave.

(iii) $V(\psi)$ is negative in the interval (0, ψ_m)

RESULTS AND DISCUSSIONS

From equation (20) we find that as U increases, amplitude (width) of the solitary waves for a given plasma system increases (decreases). It is also seen from equations (18) and (20) that the solitary potential profile is positive (negative) when A >(<)0.

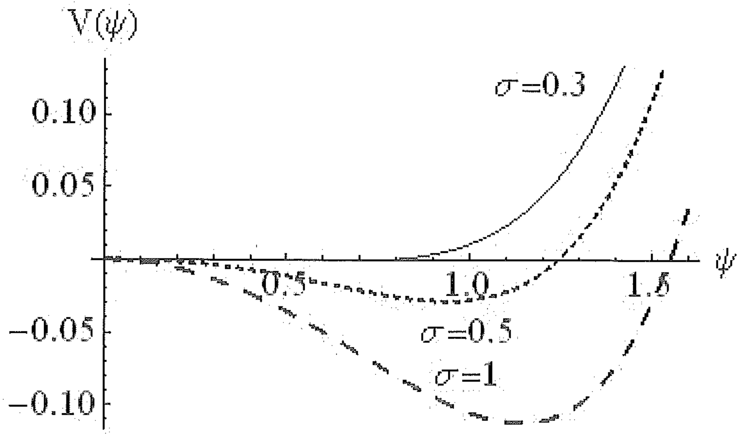

Figure 5. The variation of the potential $V(\psi)$ of the solitary waves against ψ for different values of σ, **i. e.,** σ= 0.3(solid line), σ= 0.5(dotted line) and σ=1.0 (dashed line), where M= 1.85, $\alpha=0.01$, $\beta=50$, $\mu_e=0.2$, $b=0.35$.

Results are displayed in Figures 1- 6. Figure 1 shows that the variation of amplitude of the positive solitary waves as a function of μ_e. Solid line, dotted line and dashed line are plotted for different values of β. It is observed that the amplitude of the solitary wave increases as μ_e increases and the same decreases when β increases.

Figure 2 shows that the variation of width δ_1 as a function of μ_e. Solid line, dotted line and dashed line are plotted for different values of $\beta = 5$, $\beta = 30$ and $\beta = 60$ respectively. It is seen that the width of positive solitary wave decreases slowly as μ_e increases but it increases when β increases.

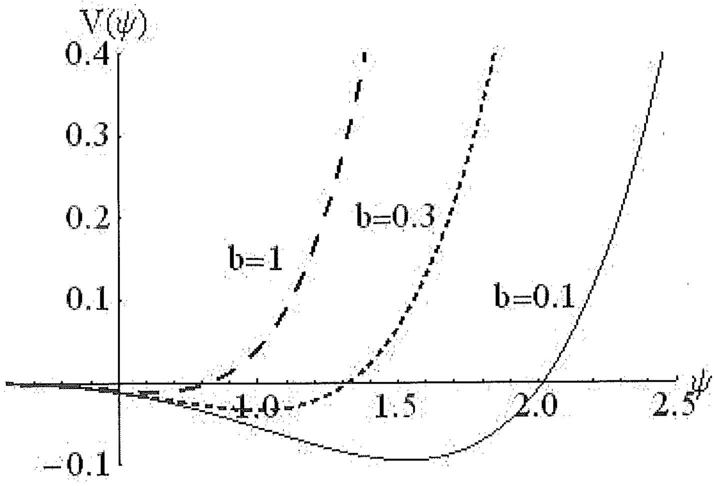

Figure 6. The variation of the potential $V(\psi)$ of the solitary waves against ψ for different values of b, i.e., b =0.1 (solid line), b = 0.3 (dotted line) and b =1.0(dashed line), where M = 1.85, $\alpha = 0.01$, $\beta = 50$, $\mu_e = 0.2$.

Figure 3 displays the variation of Mach number V_0 of positive solitary waves as a function of μ_e for different values of $\beta = 150$ for solid line, $\beta = 200$ for dotted line and $\beta = 250$ for long dashed line respectively. It has been found that the V_0 of positive solitary waves increases with increase of β but at the same time it decreases with the increase.

Figure 4 displays the variation of the potential $V(\psi)$ of the solitary waves against ψ for different values of *M*, the mach number. Here, the Mack numbers are considered as $M = 1.25$ for solid line,$M = 1.85$ for dotted line and $M = 2.0$ for dashed line respectively. It is found that the positive and negative potentials are exist when soliton velocity (Mack number) is higher. If $M = 1.25$ it indicates that only positive potential exist in the plasma system.But it is seen that when the values of M are greater than 1.25 then both negative as well as positive potentials are exist.

Figure 5 shows the variation of potential $V(\psi)$ of the solitary waves as function of ψ for several values of $M = 1.25$for solid line, $M = 1.85$ for dotted line and $M = 2.0$ for dashed line respectively. It is seen that the amplitude of thesolitary waves increases with increasing of M. And it is also seen that when $M = 1.25$ then the potential is onlypositive but for higher values of M it is seen that there is an existence of negative and positive potential in the plasma.

Figure 6 shows the variation of wave potential $V(\psi)$ of a solitary waves as a function of ψ for different values of$\sigma = 0.3$ for solid line, $\sigma = 0.5$ for dotted line and $\sigma = 1.0$ for dashed line respectively. It is clearly observed that the amplitude of the solitary waves increases with the increases of σ. It is also seen that solitons cease to exist when theparameter b crosses a certain limit. It may be mentioned that this limit may depend on the other parameters. So, itcan be noted that the vortex distributed electron has a significant role in the formation of the solitary waves.

CONCLUSIONS

In this paper, the nonlinear DASWs are studied in presence of positively and negatively charged dust by usingboth RPT and Sagdeev's pseudo potential approach. Vortex like electron distribution is considered in this model. By utilizing the standard RPT, a modified KdV equation is derived for the system. Large amplitude solitary wavesare found after analyzing the solution of modified KdV equation. Existence of large amplitude solitary waves are also studied by considering Sagdeev's pseudo potential. Finally, it is observed that the amplitude of the solitarywaves increases with the increasing of μ_e but the width of the solitary waves decreases as μ_e increases. Pseudo potential analysis indicates that the positive and negative solitary waves are exist in the plasma system. Effects ofvortex like electron distribution are found noticeable on solitary waves propagation. It is very significant that solitonscease to exist when the parameter b crosses a certain limit. It is also been noted that the positive and negative dustconcentrations, and trapped electron concentration have a significant effect on the existence of large amplitude solitary waves.

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Application of an atmospheric dielectric barrier discharge for inactivation of bacteria

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Abstract An atmospheric pressure dielectric barrier discharge (DBD) system capable of operating under both positively biased voltage pulses at 500 Hz and sinusoidal AC voltage at 8.5 kHz was constructed. The 500 Hz operation produced DBD plasma that was visually more uniform, whilst optical emission from DBD at 8.5 kHz operation was more intense. Though the inactivation of Gram-positive bacteria, *Bacillus cereus* took longer time than the Gram-negative bacteria, *Escherichia coli* ATCC 25922 and *Salmonella enteritidis*, complete sterilization was generally achieved in about 1 minute of DBD plasma treatment.

Keywords dielectric barrier discharge – inactivation of bacteria – atmospheric pressure discharge

INTRODUCTION

Atmospheric pressure non-thermal plasma has been long implemented in industrial usage with the absence of costly vacuum equipment and system. The non-thermal plasma applications include ozone generation [1], pollution control [2], surface modification [3], lighting sources [4], flat large-area plasma displays [5], and plasma medicine [6]. Several configurations have been proposed to obtain non-thermal plasma at atmospheric pressure such as dielectric barrier discharge, corona discharge, plasma jet, and One Atmosphere Uniform Glow Discharge Plasma (OAUGDP). Dielectric barrier discharge (DBD) is studied in this project as it is easy to construct and its capability of generating low temperature plasma at atmospheric pressure by utilizing the current limiting features of the dielectric barrier is advantageous for application to heat-sensitive biological samples. DBD can be built in such a way that at least one of the electrodes is covered by a dielectric layer and non-equilibrium plasma with electron temperature of 10^4-10^5 K with mean energy of range 1 eV can be generated while heavier ions remain low in energy level [6].

Active species such as electrons, ions, metastables, and free radicals generated from DBD are among the reactive agents in its related applications. The effectiveness of the DBD plasma applied to inactivation of Gram-positive and Gram-negative bacteria is examined in this paper.

EXPERIMENTAL SETUP

The DBD system constructed consisted of two parallel copper discs (diameter 3.8 cm, thickness 1 cm) as electrodes. Glass sheet (thickness 2 mm) is used as dielectric covering the high voltage electrode leaving a variable air-gap in-between. Glass is used as dielectric widely in the generation of non-thermal plasma since it is easily available and can be shaped to various arrangements. The DBD device is powered by a home-built high voltage generator (with car-coil transformer) capable of delivering up to 25 kV peak-to-peak at output frequency of 0.1 to 12 kHz as opposed to similar atmospheric pressure glass insulated barrier system which uses lower RF voltage of 1-5 kV for sterilization purpose [7]. Sub-microsecond high voltage pulses of 1-10 kHz were also utilized for the same purpose [8]. Frequency of kHz range is adopted since it's more cost friendly relative to RF system that requires commercial RF generator and impedance matching network.

The high voltage generator constructed is able to produce both (i) positively biased high voltage pulses but at low driving frequencies from 100 Hz to 2.5 kHz, and (ii) sinusoidal AC high voltage at higher driving frequencies of 6 kHz to 12 kHz. The maximum amplitude of the sinusoidal AC DBD voltage depends on the working frequency, f, according to the relation, $f = 1 \div 2\pi\sqrt{(LC)}$, where L is the inductance of the high voltage generator (6.8 ± 0.2 H) and C is the capacitance of the DBD arrangement (45-70 pF with glass dielectric at varying gap width of 0.5 to 3 mm). Hence, the frequency of operation at fixed applied voltage depends on the DBD arrangement. In the present setup, it is optimized at 8.5 kHz for the sinusoidal voltage and 500 Hz for the positively biased voltage pulses operation.

The dielectric barrier discharge is operated under atmospheric pressure. The discharge voltage is monitored via a Tektronix P6015A H.V. probe, and the current is measured by the Pearson current probe Model 4100. Spectrometer HR4000 from Ocean Optics is employed to measure the optical emission spectra from DBD plasma.

RESULTS AND DISCUSSION

For the bacteria sterilization purpose, the bacteria were exposed to the plasma generated between the electrodes. Two types of configuration were used since the type of electric field and duration of treatment could have substantial influence to the inactivation effect of bacteria [9]: (i) Positively Biased Voltage Pulses at working frequency of 500 Hz; and (ii) Sinusoidal AC Voltage at working frequency of 8.5 kHz.

Uniformity of the discharge

When the applied high voltage exceeds the breakdown criteria of the air-gap, electrical breakdown is induced and the current filaments created are known as micro-discharges [10]. The intensity and diameter of filaments determine the appearance of the discharge, either diffuse or filamentary.

Breakdown was induced with 13 kV and above for this DBD system. Positively biased voltage pulses driven DBD exhibited more uniform and diffuse discharge; while sinusoidal AC voltage powered discharge was more filamentary in appearance due to memory effect of the dielectric (Fig. 1). The residue charges from previous half breakdown cycle deposited on the dielectric surface facilitated the following half cycle by reinforcing the local field at the identical location. Thus the discharge is always ignited at old location, leading to pattern formation of the micro-discharge over the available surface [10]. The memory effect is more prominent for sinusoidal AC voltage DBD with high operating frequency.

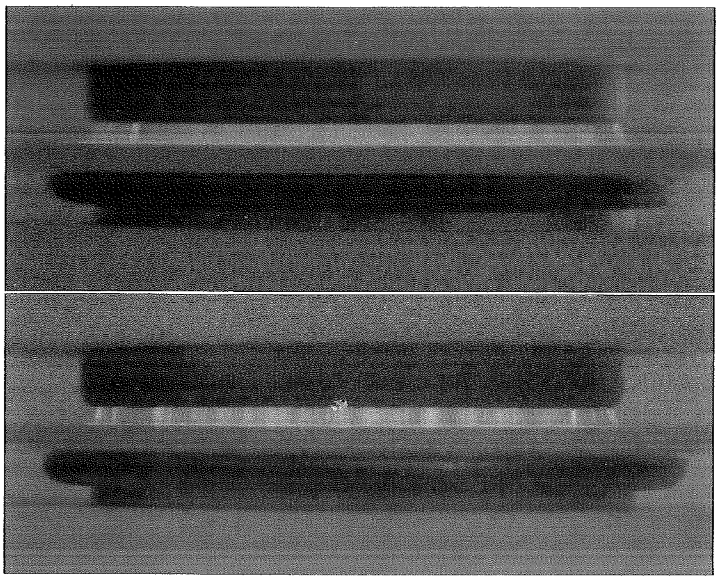

Figure 1. DBD (air-gap width 1.5 mm, single glass dielectric layer) with 500 Hz positive pulses appeared more diffuse (top), and the 8.5 kHz sinusoidal AC voltage powered DBD more filamentary (bottom) [11].

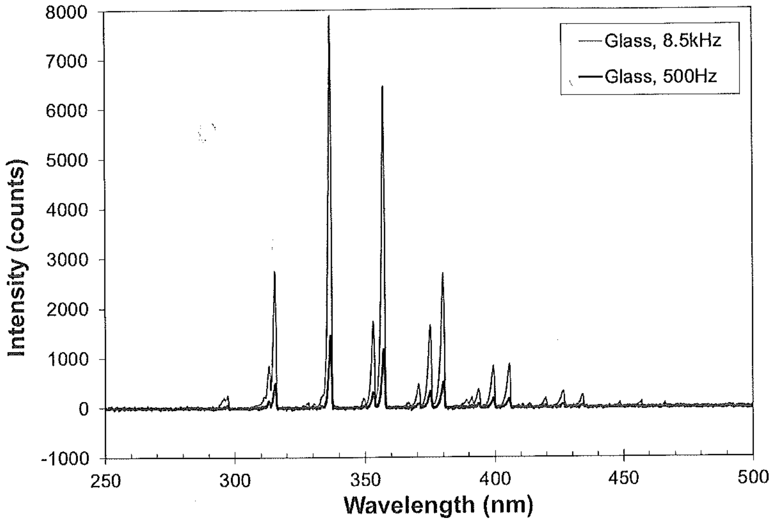

Figure 2. Emission spectra from the DBD plasma. Thinner line (registering higher peak values) represents DBD with sinusoidal voltage excitation, while the thicker line represents DBD excited by positively biased voltage pulses.

Optical emission spectra

The optical emission spectra from the DBD plasma (Fig. 2) consisted mostly of the vibrational and rotational band of the molecular nitrogen second positive system (SPS). This is consistent with the emission from non-thermal plasma in atmospheric air [12].

Inactivation of bacteria

Two types of Gram-negative bacteria (*Escherichia coli* ATCC 25922 and *Salmonella enteritidis*) and one type of Gram-positive bacteria (*Bacillus cereus*)

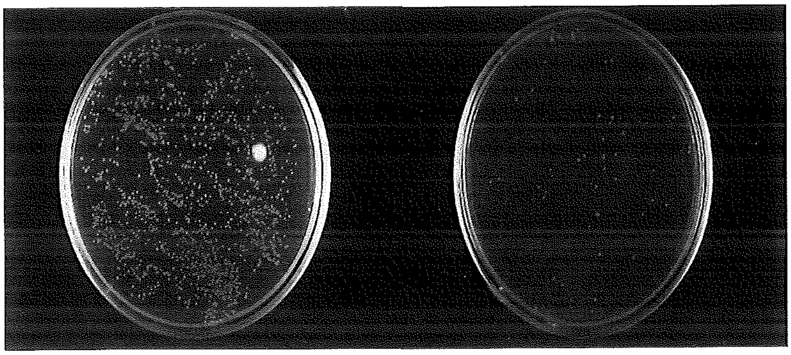

Figure 3. Control bacteria sample (left) and plasma treated bacteria sample with 15s exposure time (right).

were selected to be treated in this project. The survivability of the bacteria was studied with various treatment times (plasma exposure time). Untreated sample was used as control for each set of experiment. The colony forming unit (*cfu*) was determined after 24 hours incubation. The difference in number of *cfu* for the control and treated sample is shown in Figure 3.

The bacteria were exposed to the uniform plasma treatment with positively biased voltage pulsed excitation for the duration of 15, 30, 60, and 120 seconds. For the filamentary plasma via sinusoidal AC voltage excitation, the treatment times were 5, 10, 15, 30 and 60 seconds.

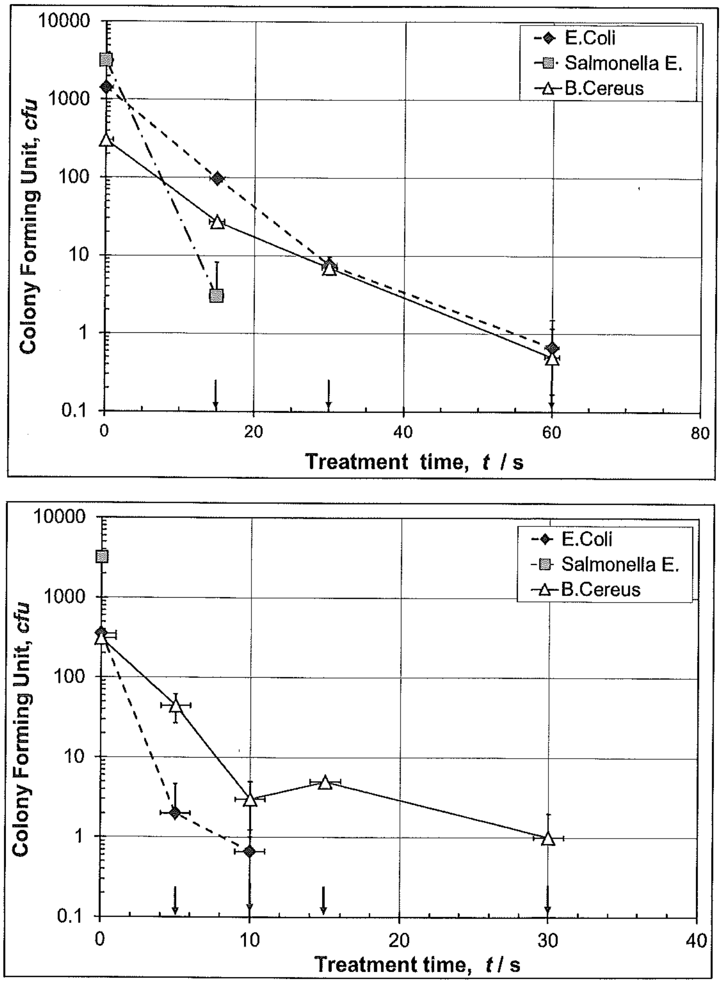

Figure 4. Survival CFU for bacteria with uniform plasma (top) and filamentary plasma (bottom) in logarithmic scale. Arrows at the horizontal axis indicates treatment time used.

The sinusoidal voltage DBD has higher sterilization power in general. Starting with 3170 *cfu* (untreated sample), complete sterilization for *Salmonella enteritidis* was achieved in more than 30 seconds of treatment time for the DBD excited by positively biased pulses (at 500 Hz) while less than 5 seconds was required for sinusoidal voltage DBD at 8.5 kHz. In the case of *Escherichia coli* with initial 1432 and 356 *cfu* in the 500 Hz and 8.5 kHz DBD systems, complete sterilization required more than 1 minute and 10 seconds, respectively. For the *Bacillus cereus* with initial 305-310 *cfu*, more than 1 minute and 30 seconds of treatment was necessary in the respective systems.

Taking into account the higher dilution of Gram-positive bacteria sample (as evident in the reduction by one order of magnitude in the *cfu*), the Gram-positive bacteria *Bacillus cereus* is more resistant to plasma sterilization as compared to the Gram-negative bacteria, *Salmonella enteritidis* and *Escherichia coli*. This is due to the thicker cell wall of Gram-positive bacteria, and may not have undergone significant disruption or morphological change after plasma treatment [13].

CONCLUSION

The plasma generated by the DBD device can effectively disinfect both Gram-negative and Gram-positive bacteria. Though the Gram-positive bacteria take longer time for complete sterilization, complete sterilization for all three samples was achieved in about 1 minute of plasma treatment. The sinusoidal voltage driven DBD system at 8.5 kHz was more efficient in inactivation of the bacteria compared to the positively biased pulsed DBD system at 500 Hz, though the latter produced more uniform plasma.

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Dependence of dielectric barrier discharge jet length on gas flow rate and applied voltage

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Abstract The effect of gas flow rate of helium and argon on the length of dielectric barrier discharge (DBD) jet generated under atmospheric pressure using an AC source is investigated. It is found that as the flow rate increases, the jet length increases up to a maximum length. Upon further increase in flow rate, it will cause the jet length to decrease. Visual inspection shows the jet to be of laminar flow when its length was increasing, and gets turbulent when the jet length decreases with increased flow rate. There is an obvious increment in jet length of argon DBD system when the applied voltage is increased from 8.8 kV to 11.0 kV, but not in helium. Spectral analysis reveals the DBD jet to comprise of emission lines of its constituent flow gas. In addition to that, emission lines of component gases (N_2 and O) in ambient air and water vapour were also present. Upstream jet was obtained only in helium DBD jet at low flow rate but high applied voltage.

Keywords dielectric barrier discharge – atmospheric pressure plasma jet

INTRODUCTION

Atmospheric pressure discharge is an electrical discharge which can be generated and controlled under atmospheric pressure. Atmospheric pressure discharges attract much interest because it is inexpensive and easy to handle, and it can be an alternative for the low pressure discharges in many applications. Much investigation that involves the physical analytical study of the discharge regimes and plasma chemistry of these discharges with dielectric barrier configuration started to boost rapidly after the 1990s [1].

There are two types of atmospheric discharge, thermal and non-thermal ones. The thermal plasma sources included transferred arc, radio frequency (RF) inductively coupled and DC plasma torch. The temperature of thermal discharges is high ranging from 5000 K to 50,000 K [2]. It is widely applied in material processing, like plasma spray to produce layers of coatings on the film [3], metal cutting [4], plasma synthesis of fine powders down to nanometer size [5] and plasma welding [6].

Examples of non-thermal atmospheric pressure discharges include corona discharge, RF discharge, dielectric barrier discharge, plasma jet and microwave discharge. To generate the non-thermal plasma at atmospheric pressure, RF, microwave, pulsed, DC or AC excitation schemes can be used. Non-equilibrium or non-thermal plasma in which the total number density of charged particles (ions and electrons) is very much less than that of the neutral particles [7], usually has gas temperature close to room temperature. However, the electrons are expected to be energetic with temperature of several electron volts (eV).

Non-thermal plasma in the form of a jet is the main interest in this work. These atmospheric pressure non-thermal plasma jets differ from the thermal type such as the plasma torch that has already been developed and used for many decades. The non-thermal type was first reported by Koinuma and co-workers in 1992 [8]. Plasma jet is attractive because it is portable and can be designed into compact size and able to operate at atmospheric pressure. Its dimension and electrode shape is flexible depending on its applications. It also can be aligned in arrays to be applied in industrial processing to increase the production efficiency [9]. There exists a variety of configurations for the plasma jet. Some commonly used configurations are those with center needle electrode, hollow or rod electrode inside quartz or glass tube, while others have electrodes outside the tube. A modified Dielectric Barrier Discharge (DBD) arrangement with external co-planar electrodes is adopted in this experiment.

The DBD is a non-equilibrium high pressure gas discharge. The discharge occurs between two electrodes with at least one of them shielded by a dielectric layer when an AC high voltage is applied. The type of dielectric will decide the proper function of the discharge [10]. There are two ways to generate the discharge, either through surface discharge or volume discharge arrangement. For volume discharge arrangement, electrodes are separated by a gas gap. The discharge bridge the gap when a high enough voltage is applied across the electrodes. For surface discharge arrangement, there is no gas gap required for this arrangement; the dielectric layer is connecting the electrodes and the discharge area is on the surface of the dielectric layer. Surface DBD was introduced by Masuda and co-workers for ozone production [11]. Quartz and glass are commonly used as dielectric materials in DBD. Dielectric material plays an important role in the control the discharge current. It will avoid transition to arc discharge in which high current flows between the two metal electrodes. This is because the charged particles that accumulate on the dielectric surface will induce an electric field which opposes the applied voltage and thus the electric field strength decreases at the location of filament formation until the filament disappears [12], hence, avoiding arc formation.

In terms of accessibility, a longer jet would be more useful. Hence, parameters that affect the formation of the atmospheric pressure DBD jet are studied in this work. This will aid in better control of the plasma jet length.

EXPERIMENTAL SETUP

Figure 1 is a schematic of the experimental setup. The plasma jet was designed with DBD configuration where both electrodes were made of copper foil, wrapped around a quartz tube (dielectric layer) in co-planar arrangement, similar to that by Xiong *et al.* [13]. One of the electrodes was connected to high voltage while the other electrode was grounded. Internal diameter of the quartz tube was 4 mm while the outer diameter was 6 mm. The width of the high voltage (HV) electrode was 10 mm while the width of the grounded electrode was 2 mm. The distance between electrodes was set at 5 mm. Distance from the edge of the quartz tube to the grounded electrode was 5 mm. Gas was continuously flowed into the quartz tube and the DBD jet was forced out from the open end of the quartz tube. The flow rate was controlled by a variable area flowmeter (Dwyer Ratemaster RMA-21) and the gases used in this experiment were Argon and Helium. The flow rate reading was corrected for different gas density as the scale was factory calibrated in air.

A home-built MOSFET driven HV generator at approximately 11 kHz was used to excite the discharge. The electrical signal was recorded by a digitizing oscilloscope (Tektronix TDS2024B), the discharge voltage was measured by a HV probe (Tektronix P6015A) while the current was measured by a current transformer (Pearson 4100). A ruler was mounted parallel to the quartz tube and Canon EOS40D camera equipped with Tamron 90 mm F/2.8 macro 1:1 lens was used to capture the image of the jet. The emission spectra of the DBD plasma jet was obtained using Ocean Optics USB2000 spectrometer which was connected to the computer for spectral display via SpectraSuite software.

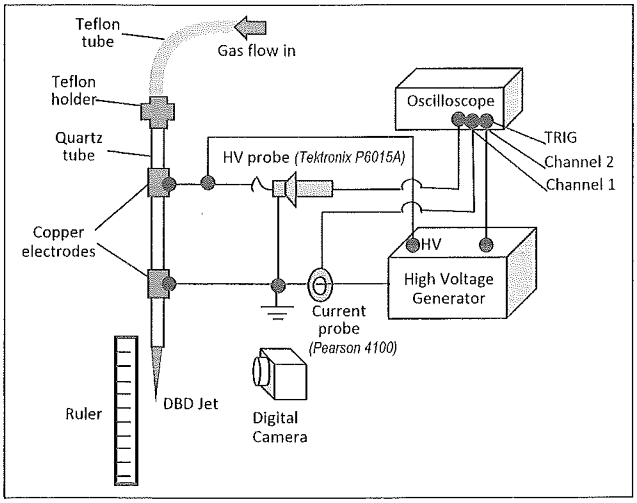


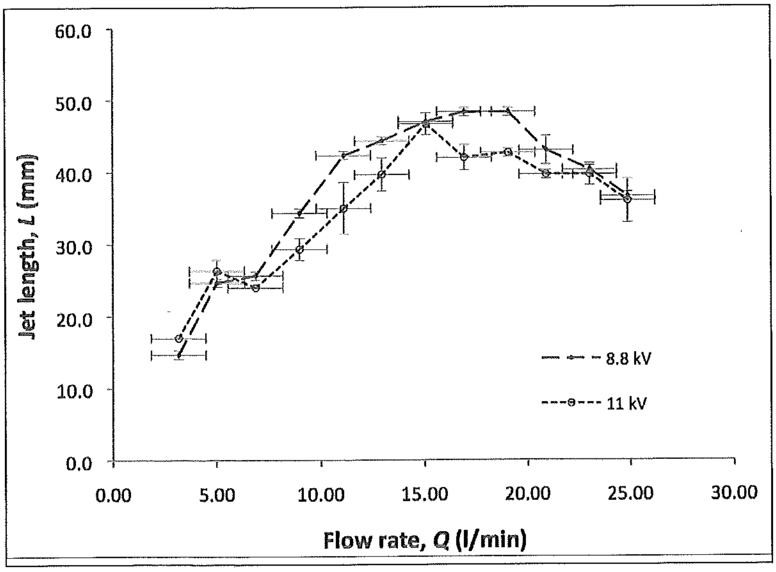
Figure 1. Schematic of experimental setup.

RESULTS AND ANALYSIS

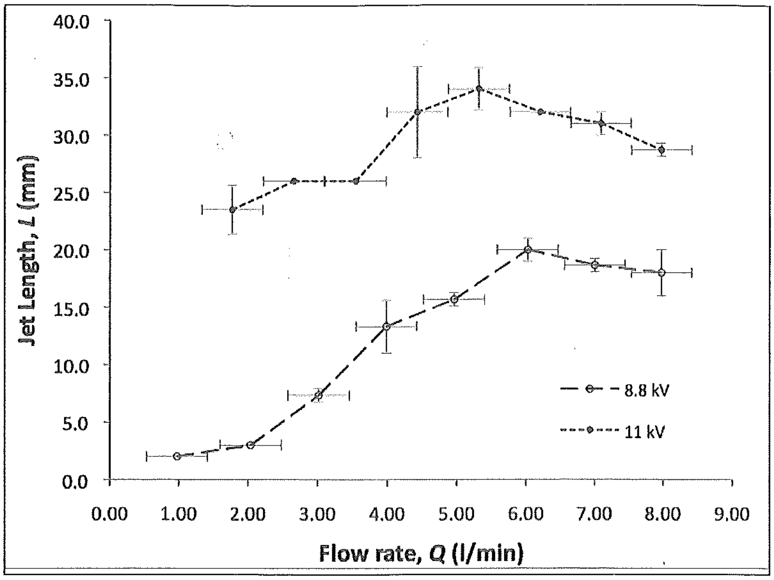
The gas flow rate, Q is one of the important parameters that can affect the DBD jet length. For both He and Ar gas, it is observed that as the flow rate, Q increases, the downstream jet length L also increases until a maximum length before decreasing with further increase in Q. In He DBD plasma jet (Fig. 2a), the longest length of the downstream jet at applied voltage (peak-to-peak), $V_{pp} \cong$ 8.8 kV occurs in the range of flow rate of 17-19 l/min. This maximum length is 48.3 mm. At $V_{pp} \cong$ 11.0 kV, maximum jet length of 46.7 mm occurs at about 15 l/min. In Ar DBD plasma jet (Fig. 2b), the longest jet length at applied voltage, $V_{pp} \cong$ 8.8 kV occurs at 6.0 l/min, with length of 20.0 mm. When excited at $V_{pp} \cong$ 11.0 kV, the maximum jet length occurs at flow rate of 5.3 l/min, with length of 34.0 mm. On visual inspection, the shape of the downstream jet is slim and tapers to a pointed end (Fig. 3a) during the length increase region. After the maximum length, the jet became wider and the end is less pointed.

It is found that only He DBD plasma jet has both downstream and upstream discharge, occurring at V_{pp} = 11.0 kV and Q = 3 l/min (Fig. 3b). The upstream discharge disappears when Q is further increased or when V_{pp} is decreased.

Emission spectra from both He and Ar DBD plasma jets (downstream) collected just outside the edge of the quartz tube exhibit emission lines from hydroxyl molecules, nitrogen molecules and oxygen atoms in addition to those from the operating gas itself. The wavelengths of these emission lines are identified and shown in Figure 4.



(a)



(b)

Figure 2. The length of DBD plasma jet, L at different flow rate, Q for (a) Helium, and (b) Argon, at applied voltages (peak-to-peak) ~8.8kV and ~11.0kV. Frequency of the AC voltage is f~11.0kHz.

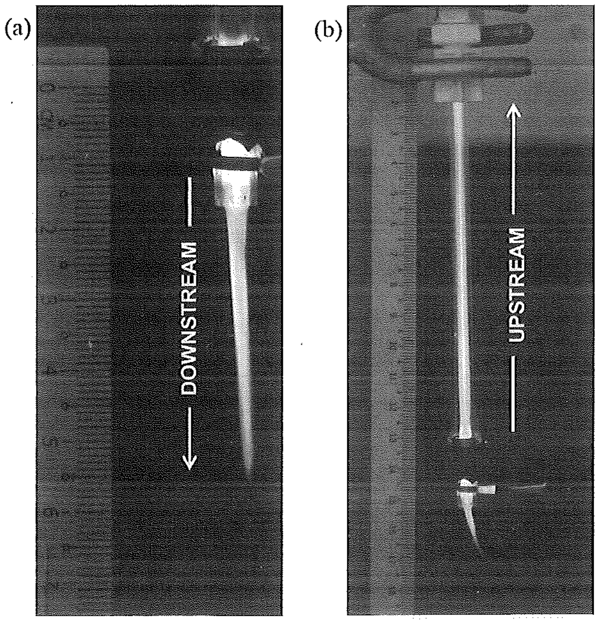


Figure 3. He DBD jet at $V_{pp} \cong 11.0$ kV. (a) Only the downstream jet is present at flow rate, $Q = 11$ l/min. (b) Both the downstream and upstream jets occur simultaneously at lower flowrate, $Q = 3$ l/min with all other parameters the same.

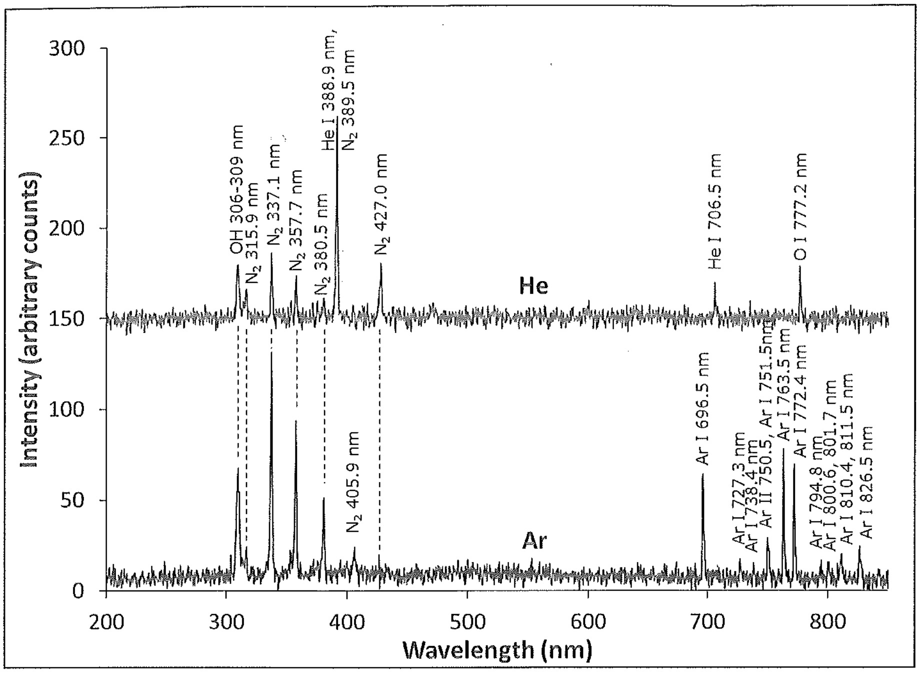


Figure 4. Emission spectra from He and Ar DBD plasma jets at V_{pp} ~ 11.0 kV, frequency, f ~ 11.0 kHz with all other parameters the same as stated earlier.

DISCUSSION

In this experiment, the frequency of the AC source was fixed at 11.0 kHz but two different voltages were applied, V_{pp} = 8.8 kV and 11.0 kV. At higher V_{pp}, the electric field strength is higher and more electrical excitation energy is applied. This will cause more ionization and thus brighter jet emission and longer jet occurs. This is very clear in Figure 2b for the case of DBD jet in Ar where L is distinctly longer when operated at V_{pp} = 11.0 kV. However, when operated in He, the jet length does not depend on applied voltage, as the DBD is operated in the glow mode (no multiple current spikes were observed in the current signal) at both voltages. The Townsend's first ionization coefficient in Ar is much larger and increases more steeply with electric field compared to He, hence, increasing the electric field tends to push the Ar DBD into filamentary mode (current spikes were observed) producing more intense discharge.

At low flow rate region, when Q is increased gradually, more gas particles are available to be ionized and number of charged particles forced out from the quartz tube would be higher, and thus a longer L is observed (Fig. 2). This is characteristic of laminar flow [14]. After achieving a maximum length, L becomes shorter when flow rate is further increased. This is most likely due to turbulence flow of the gas in quartz tube which causes lesser particles to be ejected out from the mouth of the tube. When flow rate is very high, the gas particles flowing in would be more than the number flow out from the quartz tube. This causes the velocity of gas particles to continuously change in magnitude and direction. The gas swirls and eddies but the overall bulk of the gas still moves along a specific direction which is forced out from the mouth of the quartz tube.

It is found that only He DBD plasma jet exhibits both downstream and upstream discharge at V_{pp} = 11.0 kV and low flow rate, Q = 3 l/min. However, upstream discharge no longer exists when flow rate is further increased or when the V_{pp} is decreased to 8.8 kV. The upstream jet is longer than the downstream jet because the downstream discharge diffuses into ambient air that quenches it. The upstream discharge is due to electric discharge process such as streamer mechanism in which photoionization plays an important role and not the gas flow phenomenon [15].

The presence of OH, N_2 and O emission bands/lines in the spectra of both Ar and He DBD plasma jets can be explained by the interaction of the Ar or He plasma that exits the quartz tube with the ambient air particles through excitation and de-excitation collisions. The second positive system of N_2 and O emission lines come from component gases in air while the OH band arises from water vapour content in humid air. The presence of reactive species, OH and O, will be useful for surface oxidation of polymer surfaces to increase wettability [16].

CONCLUSION

In summary, the effect of flow rate of the operating gas and applied voltage on the DBD jet length has been investigated. Jet length increases with flow rate initially up to a maximum length under laminar flow; and then the jet length decreases when the flow rate is further increased as the flow becomes turbulent. Ar DBD jet length increased markedly when applied voltage, V_{pp} is increased from 8.8 kV to 11.0 kV but not in He DBD jet. Upstream discharge occurs only in He DBD jet system when operated at flow rate of 3 l/min and V_{pp} = 11.0 kV. When the DBD jet plasma diffuses into the ambient air, N_2 molecules and O atoms as well as water molecules are also excited producing reactive species. In the present configuration, the longest jet in He is obtained at 17-19 l/min and 8.8 kV while in Ar, it is operated at 5.5 l/min and 11.0 kV.

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The Merdeka Award – Recognising Excellence and Contribution to the Nation

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Abstract The Merdeka Award was established in August 2007 by PETRONAS, ExxonMobil and Shell as a combined effort to recognise and reward Malaysians and non-Malaysians who have made outstanding and lasting contributions to the nation and the people of Malaysia in their respective fields.

INTRODUCTION

Each year on 31 August, Malaysians commemorate and celebrate Independence Day or Hari Kemerdekaan in recognition of the struggle and admirable qualities inherent in the people who rallied together to establish a sovereign land in which they could determine their own future. Merdeka is more than just a celebration of pomp and pageantry; it is about determination, resilience, honour and sacrifice, qualities of the human spirit which transcend obstacles and barriers.

There is a realisation that this *Spirit of Merdeka* should be cherished and internalised to provide motivation and inspiration in fuelling the passion amongst the current and future generations of Malaysians to excel in their chosen fields.

Achievements that bring lasting benefits to the nation, and inspire Malaysians to realise their potential should therefore be celebrated and recognised.

THE MERDEKA AWARD

The Merdeka Award was established in August 2007 by PETRONAS, ExxonMobil and Shell as a combined effort to recognise and reward Malaysians and non-Malaysians who have made outstanding and lasting contributions to the nation and the people of Malaysia in their respective fields.

ExxonMobil and Shell have been present in the country for over a century, and have journeyed with the nation through its many phases of nationhood. PETRONAS has also grown from strength to strength since its establishment in 1974, and is now an integrated petroleum multinational corporation. The Malaysian oil and gas industry has mirrored the nation's development, and has itself grown into a vital contributor to Malaysia's development and prosperity.

The establishment of the Merdeka Award is a reaffirmation of the oil and gas industry's commitment to the continued development of Malaysia and its people. This noble aspiration has united these oil and gas industry players to put aside competition and unite in their collective aim of recognising and rewarding outstanding contributions by Malaysians and non-Malaysians.

Indeed, the Founding Members of the Merdeka Award have sought to pay tribute to those who have helped make this nation great. It is a mission that honours our shared history and our common future. It stirs in our hearts the same yearning for freedom, independence and self-determination that once moved our predecessors to forge a single united nation from the many disparate communities of our lands.

This mission also guides and informs us as individuals who dedicate ourselves to the wellbeing of the communities that we come into touch with in the course of our operations. It is part of the one legacy we have inherited, and part of the one destiny we share in common with all Malaysians.

The support from Malaysians continue to sustain the Merdeka Award's mission of promoting thought leadership and innovation, fostering a culture of excellence, and encouraging global engagement to enhance Malaysia's standing as a dynamic and competitive 21st Century Global Player.

Since it was established in 2007, the Merdeka Award has honoured 28 outstanding individuals and two organisations.

The categories for the Merdeka Award are Education and Community; Environment; Health, Science and Technology; Outstanding Scholastic Achievement; and Outstanding Contribution to the People of Malaysia.

THE 2014 MERDEKA AWARD

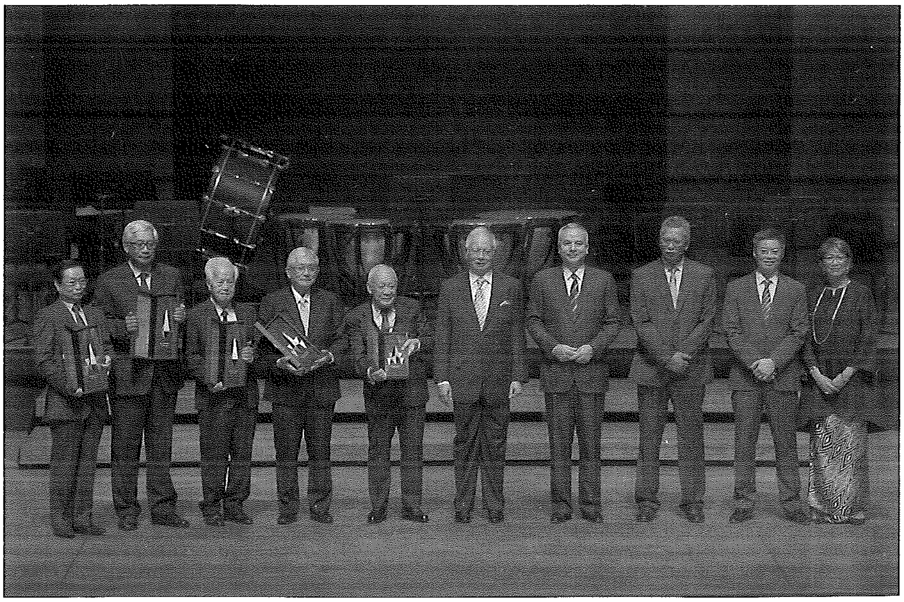
In September 2014, the 2014 Merdeka Award recipients were announced by His Royal Highness Sultan Nazrin Muizzuddin Shah, the Sultan of Perak Darul Ridzuan and Royal Patron of the Merdeka Award Trust.

The 2014 Merdeka Award recipients are:

- **Education and Community category – Datuk Mohd Nor Khalid (Lat)**
  For outstanding contribution to the promotion and pluralism of Malaysia's cultural identity through the use of cartoons and for the promotion of understanding and respect among Malaysia's diverse ethnic communities.
- **Environment category – Mohd Khan Momin Khan**
  For outstanding contribution to wildlife research and conservation through the setting up of captive breeding centres as well as for pioneering and successfully managing the human-wildlife conflict in affected areas.

- **Health, Science and Technology category – Datuk Dr Choo Yuen May**
  For outstanding contribution to the development of novel, efficient and green processes for the palm-based industry through research and commercialisation of various technologies.
- **Outstanding Scholastic Achievement category** – There are two recipients in 2014
  - **Professor Dr Abdul Latif Ahmad**
    For outstanding contribution to the scholarly research and development of technologies in the areas of polymer science, wastewater treatment and membrane separation technology.
  - **Professor Dr Ahmad Fauzi Ismail**
    For outstanding contribution to the scholarly research and development of technologies for commercialisation in membrane performance for both gas separation, and water and wastewater treatment.
- **Outstanding Contribution to the People of Malaysia category – Dato Sri Gathorne, Earl of Cranbrook**
  For outstanding contribution in pioneering research and conservation of Malaysia's forest biodiversity and the ecology and biology of Malaysian mammals and birds, and for advocating environmental conservation.

The recipients of each category receive RM500,000 cash, a trophy, a work of art by renowned Malaysian artist Latiff Mohidin and an inscribed certificate.



Merdeka Award Recipients 2013

THE MERDEKA AWARD PROGRAMMES

Creating greater public awareness of the Merdeka Award and to build its presence as an important and integral part of Malaysian life is an ongoing process. While the Award is in its nascent years, it aims to become a focal point for Malaysians to come together to reflect and be inspired to make a difference.

The Merdeka Award Trust runs two signature outreach programmes – the **Merdeka Award Roundtables,** and the **Merdeka Award Grant for International Attachment.**

The Merdeka Award Roundtables

The Merdeka Award Roundtables are a series of TV talk-shows designed to inspire debate and discussion on key issues of interest to Malaysians. First launched in August 2011, the Roundtables feature leading figures from Malaysia's corporate, academic and social spheres, coming together to discuss issues critical to the future of this nation.

The discussion and debate of the topic through the Merdeka Award Roundtables bring to life the true *Spirit of Merdeka* – that of the liberation of mind and spirit, and the pursuit of excellence. This in turn creates opportunities for Malaysians to think about how they too can play a role in the development of our country.

The 8th Roundtable, which will be broadcasted in partnership with Astro in December, addresses the topic: *"Emerging Leaders: How Will the Next Generation of Malaysians Shape the Nation?"* What are their values, and how are they prioritising the challenges and opportunities before them?

Panelists include young Malaysian leaders who represent the various perspectives that include the government, the private sector, the media, research and academic institutions and NGOs.

7th Merdeka Award Roundtable

The Merdeka Award Grant for International Attachment

The Merdeka Award Grant for International Attachment is a short-term grant designed to make it possible for qualified Malaysians between the ages of 22-35 to engage in collaborative projects/programmes at selected, internationally-recognised host institutions.

The Grant, launched in 2012, creates the opportunity for recipients to establish contact and working relationships with other experts in their fields, share knowledge and expertise, and upon their return, use these relationships and shared knowledge to further build on the body of work in his or her area of research.

Two Grants are offered annually to successful candidates in select disciplines – Education and Community, Environment as well as Health, Science and Technology, mirroring the categories in which the Merdeka Award itself is accorded. The broad categories include areas such as visual and performing arts, heritage and social work, sports; traditional disciplines like economics and finance, scientific disciplines, and areas related to the environment such as climate change, biodiversity and the protection and conservation of the environment. These categories have been carefully selected because of the importance of these disciplines to the progress of the country.

The Attachment is made possible and facilitated through the global network and reach of the three Merdeka Award founding partners – PETRONAS, ExxonMobil and Shell.

Applications for the 2015 cycle of the Merdeka Award Grant for International Attachment will close on December 31, 2014.

Merdeka Award Grant Recipients 2014.