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Influence of NPK fertilizer rates and irrigation frequencies on the biomass and yield components of sweet corn (*Zea mays* L.)

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Abstract

Application of adequate fertilizers becomes one of the most important agronomic practices to sustain corn production on soils of the tropical regions, which are mostly acidic and poor in nutrients. An experiment under rain shelter was conducted at the Faculty of Agriculture, Universiti Putra Malaysia, Serdang to evaluate the influence of different NPK fertilizer rates on the biomass and yield components of sweet corn. The experiment was carried out using split plot design with four replications. Three drip irrigation frequencies as a main plot: [Once in 2 days (Ir1), once in 3 days (Ir2) and once in 4 days irrigations (Ir3)] and four NPK fertilizer rates as sub-plot [0:0:0 (0%), 60:30:45 (50%), 120:60:90 (100%) and 180:90:135 (150%), henceforth referred to as F1, F2, F3 and F4, respectively] were tested in this experiment. The results of the study showed that total dry matter significantly ($P<0.05$) increased with increase in the irrigation frequencies. For Ir1 treatments at F4 fertilizer rate, the shoot dry weight was higher compared to the other fertilizer rates due to better nutrient supply to the plant. Similarly, irrigation frequency and fertilizer levels significantly ($P<0.05$) influenced the yield components. Ear, cob and grain were found to have higher weight for once in 2 days irrigation frequency with fertilizer level of F4. When fertilizer rate was increased from 100% (F3) to 150% (F4), ear, cob and grain weight were increased by 25%, 39% and 23%, respectively.

Key words: Drip irrigation, fertilizer rates, sweet corn, water stress, Ultisol.

Introduction

Corn ranks second to wheat in terms of cereal production in the world [1]. Globally, the United States of America leads the production of corn, followed by China and Brazil [2]. Sweet corn is a multi-purpose crop, which is used for human consumption, animal feed, industrial raw material and fuel [3]. In tropical and semi-arid countries, low corn production is due to many factors, such as infertile soil, soil acidity, unbalance nutrient supply and lack of skills in terms of fertilizer application [4]. Water scarcity is another important factor that can reduce corn production throughout growth stages. Water unavailability limits corn growth by way of reducing the uptake of macronutrients [5]. Payero *et al.* [6] reported that soil water deficit during any of the plant growth cycle can cause a reduction in the growth and yield. Drip irrigation is an important way in the management of water in agriculture sector to sustain crop productivity. Applying fertilizers, either inorganic or organic, can also contribute to increased crop produtivity [7]. The main purpose of fertilizer application to any crop is to improve soil fertility and consequently, getting high crop yields [8].

Nitrogen is the most important nutrient and yield-determining factor, therefore, its availability in the soil in sufficient quantity during the growing stages is essential for optimum corn growth and yield [9, 10]. Corn has been reported to have high response to nitrogen fertilization, and an increase in N application can increase crop growth and yield [11, 12]. Phosphorus is another major nutrient required by the corn in a large quantity though the amount required by the corn is less than that of N [13]. Potassium requirement by the corn is high; corn absorbs K in higher quantity compared to any other elements, except for N. Phosphorus enhances root development and due to which the yield and vegetative growth of corn is increased [14].

In Malaysia, corn is grown mostly on highly weathered and acidic soils. The yield of corn planted on these soils is low due to low soil fertility, low pH, low exchangeable Ca and Mg, and high exchangeable Al [15]. These soils (which are among the most widespread soil type in the tropics) are classified as Ultisols and Oxisols [16]. It is reported that the critical pH for corn production on the Ultisols of Malaysia is 4.7 [15], while critical Al concentration is 22 µM [17]. With low pH of about 4.5, Al concentration in the soil solution under field condition can exceed the critical level for corn growth. Therefore, to alleviate Al toxicity for corn production, ground magnesium limstone (GML) has to be applied at the appropriate rate. However, the effect of lime application is only confined to the zone of incorporation [15, 18]. According to Shamshuddin *et al.* [17], the amount of GML required to alleviate soil acidity for corn production in Malaysia was 2 t GML ha^{-1}. Applying GML on Ultisols in Malaysia at this rate would effectively last more than 4 years. Hence, this study was conducted to determine the effects NPK fertilizer rates and drip irrigation frequencies on the growth and yield of sweet corn planted on an Ultisol having Al toxicity problem.

Materials and Methods

Experimental site and conditions: This experiment was conducted at Field 2, Faculty of Agriculture, Universiti Putra

Malaysia, Serdang, Malaysia. The study site was located at an altitude of 30 m above sea level, and at the latitude of 30.01°N and longitude of 101.70°E. The seeds of corn were sown under rain shelter to prevent the effect of rainfall on the crop. Bungor Series, classifed as Ultisol, was selected for this study [15]. The physico-chemical characteristics of the untreated topsoil are given in Table 1.

Table 1. Physico-chemical characteristics of the topsoil of Bungor soil.

Chemical parameters	Values	Physical parameters	Values
pH	4.8	Particle size distribution (%)	
EC (mS cm^{-1})	0.14	Sand	56.13
CEC (cmol$_c$ kg^{-1})	16.9	Silt	8.24
Total N %	0.84	Clay	35.54
Total C %	1.23	Bulk density (Mgm^{-3})	1.3
Available P (mg kg^{-1})	54.80	Porosity (%)	52.3
Exchangeable (cmol$_c$ kg^{-1})		Soil moisture content (mc)	12.5
Ca	0.22	Field capacity (%)	18.2
Mg	0.55	Wilting point %	12.7
K	0.24		
Al	1.79		

Experimental design: The treatments were arranged in a split plot design, with four replications. Irrigation treatments were assigned as the main plot, while NPK fertilizer rates as the sub-plot factor. The types of irrigation used for this study was drip irrigtion since it is the most efficient irrigation system in terms of water safety and management. Three drip irrigation frequencies were used: Once in 2 days (Ir1), once in 3 days (Ir2) and once in 4 days (Ir3). The NPK fertilizer levels were: 0% (F1); 50% (F2); 100% (F3) and 150% (F4) of the recommended fertilizer rate by the Malaysian Agricultural Research and Development Institute (MARDI), which is 120:60:90 kg ha^{-1} of N:P_2O_5:K_2O. The fertilizers were applied during the planting time except N which was half applied at the planting time and the remaining half 30 days after sowing (DAS) to reduce leaching and volatilization losses of N [19].

In this study, water was supplied to the sweet corn at 90, 80 and 70% of soil water field capacity for irrigation Ir1, Ir2, and Ir3, respectively. The drip irrigation system was divided into main water source from which the water come through polypipes (32 mm diameter). Then, the water was distributed to the polybags by microtubes that had valves to control water passage, and each plant received the water through the small dripper that was located at the end of the microtubes.

Soil moisture measurement: Soil water field capacity was measured according to the irrigation schedule especially before irrigation to determine the volumemetric water content (vwc). This was done using 10HS Soil Moisture Sensor, USA, by which the soil moisture scale was kept under control (not to reach the permanet wilting point).

Soil analysis: Soil chemical and physical characteristics were analysed before the seed of the corn were sown as shown in Table 1. The pH of the soil was determined in water (1:2.5; soil:water), while electrical coductivity was measured by a glass electrode EC meter. Cation exchange capacity (CEC) was determined by the method of Schollenberger and Simon [20] in which 1 M NH_4OAc buffered at pH 7.0 was used. Basic cations (Ca, Mg and K) in the NH_4OAc solutions were analysed by atomic absorption spectrophotometer (AAS). Exchangeable Al was extracted with 1 M KCl and determined colorimetrically [21]. Total N was determined by the Kjeldahl method [22] and available P by the Bray and Kurtz method [23], while organic carbon was determined by the Walkey-Black method [24]. Particle-size distribution was determined by the pipette method of Day [25]. Bulk density and porosity were determined by core ring method, soil field capacity and wilting point by pressure plate, while moisture contents by gravimetric method [26].

Plant parameters and analysis: Plants were measured for biomass such as total dry matter (TDM) and yield components namely: Ear and cob weight per plant, ear diameter, ear length and 100 grain weight. To determine the amount of nutrients in the leaves and roots, plant tissue analysis was carried out after the leaves and root had been dried and ground. For the tissues analysis, 0.25 g sample was digested using wet ash method. The digested sample was used to determine the N, P, K, Ca and Mg contents in the tissues [27]. Nitrogen, phosphorus and potassium were analysed by auto-analyser (Lachat Instrument, USA), while Ca and Mg were determined by atomic absorption spectrophotometer (Perkin Elmer 5100, USA). Analysis of variance (ANOVA) of sweet corn yield parameters and nutrients uptake are given in Table 2 and Table 3, respectively.

Table 3. Analysis of variances (ANOVA) of nutrient uptake in the root and leaf traits.

Treatments	Root					Leaf				
	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Irrigation frequencies (I)	*	**	**	ns	*	ns	ns	ns	ns	ns
Fertilizer levels (F)	**	**	**	*	*	**	**	**	**	**
I*F	**	**	*	ns	ns	ns	ns	ns	ns	ns

*= significant at 0.05 level; **= significant at 0.01 level; ns= not significant.

Statistical analysis: Data collected from this study were analysed using analysis of variance (ANOVA) and the difference between the means was compared by Duncan's Multiple New Range Test (DMNRT) using SAS soft word version 9.2 (Sas Inc., USA).

Table 2. Analysis of variances (ANOVA) of total dry matter and yield component traits.

Treatments	Shoot weight (g)	Root weight (g)	Ear weight (g)	Cob weight (g)	Ear length (cm)	Ear diameter (mm)	100 grain weight (g)
Irrigation frequencies (I)	*	**	*	*	ns	ns	ns
Fertilizer levels (F)	**	**	**	**	**	**	**
I*F	*	*	ns	ns	ns	ns	ns
CV	18.5	23.6	24.5	21.5	11.1	14.9	23.1

*= significant at 0.05 level; **= significant at 0.01 level; ns= not significant; CV= coefficient of variation.

Results and Discussion

Total dry matter of sweet corn: Total dry matter of sweet corn (shoots and roots) as influenced by irrigation frequencies and fertilizer rates are presented in Figs 1 and 2. There was significant (P<0.05) interaction between irrigation frequencies and fertilizer levels on shoot dry weight of sweet corn. For Ir1, treatments with 150% (F4) and 100% (F3) of the recommended rate gave higher shoot dry weight (68.23 g plant^{-1} and 79.34 g plant^{-1}), respectively, compared to 50% (F2) and 0% (F1) of the recommended rate. For Ir2 treatment, the plants that received the highest fertilizer level [150% (F4)] of the recommended rate gave the highest shoot dry weight (63.29 g plant^{-1}). Treating the corn at F1 of the recommended rate recorded the lowest shoot dry weight (24.11 g plant^{-1}). Similarly, for once in 4 days irrigation frequencies (Ir3), the highest fertilizer level [150% (F4)] gave the highest shoot dry weight (63.92 g plant^{-1}) (Fig. 1).

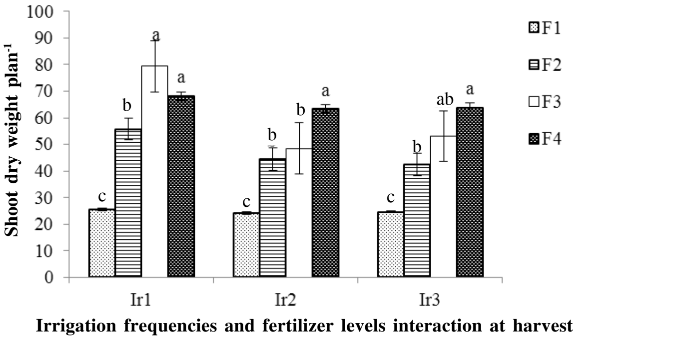

Figure 1. Shoot dry wieght of sweet corn as influenced by irrigation frequencies and fertilizer levels at harvest.

[Ir1: Once in 2 days, Ir2: Once in 3 days, Ir3: Once in 4 days irrigation. F1: 0% of RFR, F2: 50% of RFR, F3: 100% of RFR, F4: 150% of RFR, RFR = recommended fertilizer rate (120:60:90 kg ha^{-1}, N:P_2O_5:K_2O)]. Means with the same letter within irrigation frequency are not significantly different.

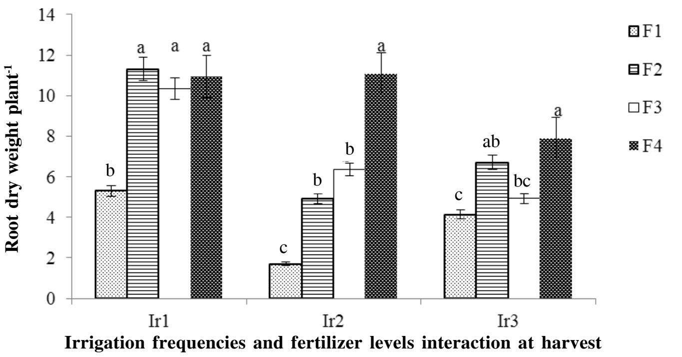

Figure 2. Root dry weight of sweet corn as influenced by irrigation frequencies and fertilizer levels at harvest.

[Ir1: Once in 2 days, Ir2: Once in 3 days, Ir3: Once in 4 days irrigation. F1: 0% of RFR, F2: 50% of RFR, F3: 100% of RFR, F4: 150% of RFR, RFR = recommended fertilizer rate (120:60:90 kg ha^{-1}, N:P_2O_5:K_2O)]. Means with the same letter within irrigation frequency are not significantly different.

Irrigation frequencies significantly (P<0.01) influenced root dry weight of sweet corn. The weight of the root increased with increase in irrigation frequency. Once in 2 days irrigation (Ir1) yielded higher root dry weight (9.48 g plant^{-1}) compared to once in 3 days irrigation (Ir2) (6.00 g plant^{-1}) and once in 4 days irrigation frequencies (Ir3). Fertilizer levels significantly (P<0.01) affected root dry weight of sweet corn. Treating the corn at F4 gave higher root dry weight (9.96 g plant^{-1}) compared to other fertilizer levels. Significant (P<0.05) interaction between irrigation frequency and fertilizer levels on root dry weight was noted. For once in 2 days irrigation frequencies (Ir1), the lowest fertilizer level resulted in lower root dry weight (5.31 g plant^{-1}). However, for once in 3 days irrigation frequencies (Ir2) and once in 4 days irrigation frequencies, the plants that received the highest fertilizer level [150% (F4)] gave the highest root dry weight of sweet corn.

Hence, both total shoot dry weight and root dry weight of sweet corn increased with increase in irrigation frequencies. As more number of leaves were exposed to sunlight, total shoot dry weight progressively increased due to regular availability of soil moisture. Water applied during the early growth stage of plant increased the process of biomass accumulation [28]. Reductions in biomass at the beginning of the tasseling and plant pollination of the sweet corn due to water stress have been reported by other researchers [29, 30]. Water deficit during late vegetative growth stage not only reduced biomass but also decreased the number of leaves, stem elongation and decreased number of kernels [28]. Stone *et al.* [31], Osborne *et al.* [32] and Moser *et al.* [33] reported that total biomass and yield components of sweet corn were reduced by moisture stress.

In terms of fertilizer levels, plants that received highest fertilizer level of 150% (F4) of the recommended rate gave an appreciable total shoot weight (Fig. 1) due to high N (63.48 g plant^{-1}) and K uptake (56.36 g plant^{-1}) by the corn. Similarly, based on root biomass, plants that received 150% (F4) of the recommended rate had more dry weight in Ir2 and Ir3 due to high N uptake (11.95 g plant^{-1}) and K uptake (23.70 g plant^{-1}). However, for Ir1, plants that received 0% (F1) of the recommended rate recorded the lowest root dry weight (Fig. 2) due to low nutrient supply. Liang and MacKenzie [34] reported that total dry yield linearly increased with increase of fertilizer rate which indicates positive response of nutrients by the sweet corn.

Yield components: The yield components of sweet corn namely ear fresh weight, cob fresh weight, ear length, ear diameter and 100 grain weight as influenced by irrigation frequencies and fertilizer levels are pressented in Table 4. Irrigation frequencies significantly (P<0.05) affected ear weight of sweet corn. The weight of the ear increased with increase in irrigation frequency. Ir1 was found to give higher ear weight (96.80 g plant^{-1}) compared to Ir3 (77.21 g plant^{-1}). Fertilizer levels also significantly (P<0.01) influenced ear weight of the sweet corn. Plants that received the highest fertilizer level of 150% (F4) of the

Table 4. Effects of irrigation frequency and fertilizer levels on yield components.

Treatments	Yield components weight (g plant^{-1})				
	Ear	Cob	Ear length	Ear diameter	100 grains
Irrigation frequencies					
Ir1	96.80a	65.32a	25.53a	37.70a	17.40a
Ir2	84.32ab	63.40a	25.03a	36.13a	17.90a
Ir3	77.21b	50.09b	24.08a	36.40a	15.38a
Fertilizer levels					
F1	30.80d	14.16d	20.00c	25.70c	1.46c
F2	74.60c	53.20c	23.70b	37.40b	21.20b
F3	102.50b	64.60b	27.40a	40.04ab	19.50b
F4	136.50a	106.50a	28.40a	44.00a	25.40a

Means within same column with similar letters are not significantly different at (P<0.05). [Ir1: Once in 2 days, Ir_2: Once in 3 days, Ir_3: Once in 4 days irrigation, F1: 0% of RFR, F2: 50% of RFR, F3: 100% of RFR, F4: 150% of RFR, RFR = recommended fertilizer rate (120:60:90 kg ha^{-1}, N:P_2O5:K_2O)].

recommended rate resulted in higher ear weight (136.5 g plant^{-1}) compared to other fertilizer levels. This was 24.9, 45.35 and 77.44% higher than that of F3, F2 and F1, respectively.

Irrigation frequency signigicantly (P<0.01) influenced cob fresh weight of the sweet corn. Ir3 recorded the lowest cob weight (50.09 g plant^{-1}). Fertilizer levels significantly (P<0.01) affected cob weight of the sweet corn. Plants that received 150% (F4) of the recommended rate had higher cob weight (106.50 g plant^{-1}), which were 39.34, 50.05, and 86.70 higher than that of F3, F2 and F1, respectively. Fertilizer rates significantly (P<0.01) influenced ear length and ear diameter of the sweet corn. Treating the corn at 150% (F4) and 100% (F3) of the recommended rate gave higher ear length compared to treatments F2 and F1. Similarly, fertilizer levels significantly (P<0.01) affected 100 grain weight of the sweet corn. Plants that received the highest fertilizer level [150% (F4) of recommended rate] gave higher grain weight (24.40 g) compared to that of F3, F2 and F1 with the value of 19.50, 21.20 and 1.46 g, respectively. Irrigation frequencies did not affect ear length, ear diameter and 100 grain weight of the sweet corn (Table 4).

Yield components especially cob fresh weight, ear fresh weight, and diameter were significantly (P<0.01) influenced by fertilizer levels. Plants that received the highest fertilizer level [150% (F4) of the recommended rate] had more weight (Table 4) due to better nutrient supply to the them. Oktem and Oktem [35] reported that fresh ear dry weight, kernel number ear^{-1} and ear length increased with the increase in N rate. Eshghizadehb [36] reported that total dry matter of maize increased with increase of N levels up to 144 kg N ha^{-1} and further increase in N to 160 kg N ha^{-1} doubled the number of kernel ear^{-1} and grain yield. Similar results have been reported by Cerrato and Blackmer [37]. Ali *et al.* [38] found that application of N:P_2O_5 at 150:90 kg ha^{-1} gave maximum grain yield of sweet corn. Applying P alone at 20 to 60 kg P_2O_5 ha^{-1} significantly increased sweet corn corn yield [13]. Similar findings were reported by Oad *et al.* [4]. Moreover, significant correlation was observed between ear weight plant^{-1}, cob weight plant^{-1} and 100 grain weight and shoots and root biomass (Table 5). Thus, it indicated clearly that increasing dry matter enhanced the yield of corn.

Table 5. Correlation coefficients (r) between yield components and biomass of sweet corn.

Variable	Shoot dry weight	Root dry weight
	(g plant^{-1})	
Ear weight (g) plant^{-1}	0.79**	0.69**
Cob weight (g) plant^{-1}	0.68**	0.60**
100 grain weight (g)	0.66**	0.66**

**= significant at 0.01 level.

Effects of irrigation frequencies and fertilizer rates on corn nutrient uptake nitrogen uptake: There were significant (P<0.01) interaction between irrigation frequencies and fertilizer rates on N uptake of sweet corn roots (Fig. 3). At all the irrigation frequencies, plants that received the highest fertilizer rates of 150% (F4) had higher N uptake by the roots (17.07 g plant^{-1}, 9.54 g plant^{-1}, and 9.24 g plant^{-1} at Ir1, Ir2 and Ir3, respectively). However, for once in 4 days irrigation frequencies, there were no significant difference between F4 and F3. In terms of the leaves, irrigation frequencies did not affect N uptake. Fertilizer rates significantly (P<0.01) influenced N uptake of the sweet corn leaves. The highest fertilizer rates [150% (F4)] gave higher

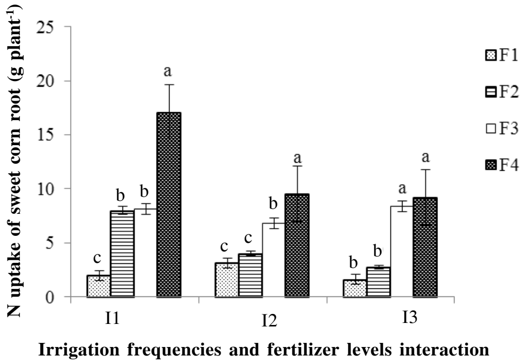

Figure 3. N uptake of sweet corn root as influenced by irrigation frequencies and fertilizer levels.
[Ir1: Once in 2 days, Ir2: Once in 3 days, Ir3: Once in 4 days irrigation. F1: 0% of RFR, F2: 50% of RFR, F3: 100% of RFR, F4: 150% of RFR, RFR = recommended fertilizer rate (120:60:90 kg ha^{-1}, N:P_2O_5:K_2O)]. Means with the same letter within irrigation frequency are not significantly different.

N uptake (63.48 g plant^{-1}) compared to that of F3 (47.06 g plant^{-1}), F2 (37.76 g plant^{-1}) and F1 (17.13 g plant^{-1}). This indicates that sweet corn responded to fertilizer application by enhancing corn biomass due to higher N uptake. This is reflected by the linear positive correlation between root dry weight and N uptake by the root (r=0.61, P<0.01) and positive correlation between total shoot dry weight and N uptake by the leaves (r=0.69, P<0.01). Furthermore, N uptake of sweet corn by its roots and leaves was enhanced by the high fertilizer application [150% (F4)] as shown in Table 7, which indicated higher N concentration in the plants. It was pointed out that nutrient uptake especially nitrogen increased crop production [39].

Phosphorus uptake: Interaction between irrigation frequencies and fertilizer rates (P<0.01) on P uptake of the root was noted (Fig. 4). For once in 2 days irrigation (Ir1), the highest P uptake of sweet corn roots was obtained from the highest fertilizer rates of 150% (F4) of the recommended rate F4 (4.08 g plant^{-1}). For once in 3 days irrigation (Ir2), fertilizer level of 100% (F3) recorded the lowest P uptake (1.1 g plant^{-1}). For once in 4 days irrigation (Ir3), fertilizer level of 150% (F4) and 100% (F3) yielded higher P uptake (2.08 g plant^{-1}) and (1.55 g plant^{-1}), respectively compared to 50% (F2) and 0% (F1). Fertilizer rates significantly (P<0.01) influenced P uptake of the sweet corn leaves (Table 6). P uptake in the leaves increased with the increase

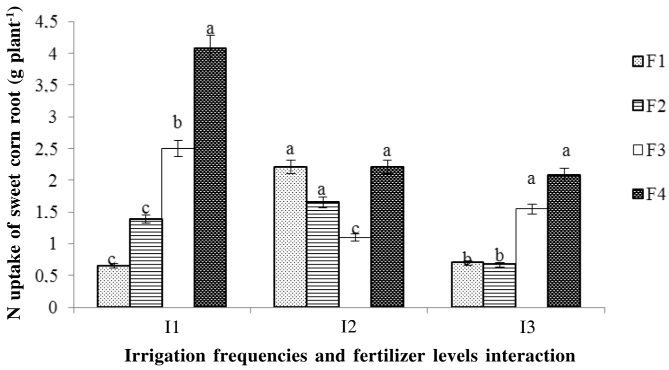

Figure 4. P uptake of sweet corn root as influenced by irrigation frequencies and fertilizer levels.
[Ir1: Once in 2 days, Ir2: Once in 3 days, Ir3: Once in 4 days irrigation. F1: 0% of RFR, F2: 50% of RFR, F3: 100% of RFR, F4: 150% of RFR, RFR = recommended fertilizer rate (120:60:90 kg ha^{-1}, N:P_2O_5:K_2O)]. Means with the same letter within irrigation frequency are not significantly different.

Table 6. Effects of irrigation frequency and fertilizer levels on nutrient uptake of sweet corn.

Treatments	Root nutrient uptake		Shoot nutrient uptake				
	(g $plant^{-1}$)						
	Ca	Mg	N	P	K	Ca	Mg
Irrigation frequencies							
Ir1	0.07a	1.54a	45.09a	5.58a	38.50a	4.85a	3.83a
Ir2	0.07a	0.91b	37.87a	4.91a	40.49a	4.89a	3.54a
Ir3	0.05a	0.86b	41.12a	5.50a	41.15a	4.99a	3.65a
Fertilizer sources							
F1	0.03b	0.40c	17.13d	2.86c	21.32c	2.27c	2.09c
F2	0.05b	1.01b	37.76c	4.79b	39.92b	5.19b	3.99b
F3	0.07ab	1.21b	47.06b	5.27b	42.59b	5.22b	3.45b
F4	0.11a	1.78a	63.48a	8.41a	56.36a	6.96a	5.14a

Means within same column with similar letters are not significantly different at (P<0.05).
[Ir1: once in 2 days, Ir_2: once in 3 days, Ir_3: once in 4 days irrigation, F1: 0% of RFR, F2: 50% of RFR, F3: 100% of RFR, F4: 150% of RFR, RFR = recommended fertilizer rate (120:60:90 kgha^{-1}, N: P_2O5:K_2O)].

in fertilizer rates. Treating corn at F4 of the recommended rate gave higher P uptake (8.41 g $plant^{-1}$) compared to other fertilizer levels. Irrigation frequency did not influence P uptake of the sweet corn leaves and there were no interactions between irrigation frequencies and fertilizer levels. It indicates that sweet corn progressively responded to fertilizer application by increasing total dry biomass. This is reflected by the simple linear positive correlation between root dry weight and P uptake of the root (r=0.58, P<0.01) and between shoot dry weight and P uptake of the shoots (r=0.69, P<0.01) (Table 5). Similar findings were reported by Ali *et al*. [38] and Kogbe and Adediran [13].

Potassium uptake: Interaction between irrigation frequencies and fertilizer rates on K uptake by sweet corn root is presented in Fig. 5. For once in 2 days irrigation Ir1, the highest K uptake of sweet corn root was obtained from the treatment of 150% (F4) (38.00 g $plant^{-1}$). Potassium uptake by the sweet corn shoot was not influenced by irrigation frequency; however, it was significantly (P<0.01) increased by fertilizer rates. The highest K uptake was observed from treatment F4 (Table 6). There was significant increase in K uptake of the sweet corn shoots, as the fertilizer rate increased, due to increased growth of shoot and root. This is reflected by the positive correlation between root biomass and K uptake by the root (r=0.58, P<0.01) and between shoot dry weight and K uptake by the leaves (r=0.62, P<0.01) (Table 7). Similar findings were reported by Kogbe and Adediran [13].

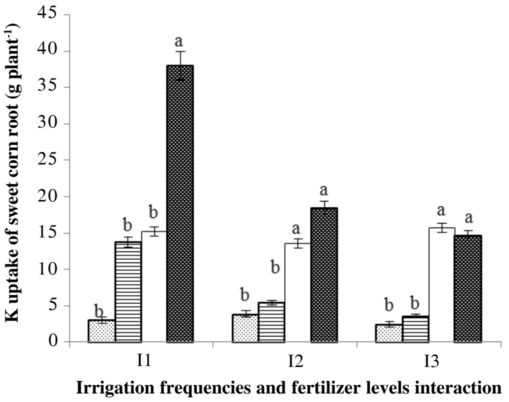

Figure 5. K uptake of sweet corn root as influenced by irrigation frequencies and fertilizer levels.
[Ir1: Once in 2 days, Ir2: Once in 3 days, Ir3: Once in 4 days irrigation. F1: 0% of RFR, F2: 50% of RFR, F3: 100% of RFR, F4: 150% of RFR, RFR = recommended fertilizer rate (120:60:90 kg ha^{-1}, N:P_2O_5:K_2O)]. Means with the same letter within irrigation frequency are not significantly different.

Table 7. Correlation coefficients (r) between yield parameters and nutrient uptake.

Variables	Root	Shoot	Ear weight	Cob weight	100 grain weight
N	0.61**	0.69**	0.71**	0.72**	0.63**
P	0.58**	0.69**	0.71**	0.72**	0.61**
K	0.58**	0.62**	0.70**	0.70**	0.60**
Ca	0.33**	0.42**	0.44**	0.41**	0.42**
Mg	0.54**	0.62**	0.55**	0.56**	0.54**

**,* = Significant at P<0.01 and P<0.05, respectively.

Calcium uptake: Calcium uptake by sweet roots as influenced by irrigation frequencies and fertilizer rates are presented in Table 6. Fertilizer rates significantly (P<0.01) affected Ca uptake of the sweet corn roots. Higher rate of fertilizer application [150% (F4)] resulted in higher Ca uptake of the sweet corn root (0.112 g $plant^{-1}$). Irrigation frequencies did not influence Ca uptake of the sweet corn roots. On the other hand, Ca uptake of sweet corn leaves was significantly (P<0.01) influenced by irrigation frequencies. Plants that received the highest fertilizer rate [150% (F4)] had more Ca uptake (6.96 g $plant^{-1}$) compared to other fertilizer rates. There were no significantly interactions between irrigation frequencies and fertilizer rates on the Ca uptake of sweet corn roots. The high Ca uptake by the corn shoots and roots was due to improved shoot and root growth. This is shown by the positive correlation between root dry weight and Ca uptake by the root (r=0.33, P<0.05) and between total shoot dry weight and Ca uptake by leaves (r=0.43, P<0.01) (Table 7). Increase in Ca uptake by the roots and shoots of the crop indicates the positive response of the plants to fertilizer application, as the Ca is necessary for formation of the structural macromolecules [40].

Magnesium uptake: Influence of irrigation frequencies and fertilizer rates on Mg uptake by sweet corn roots and leaves are presented in Table 6. Fertilizer rates significantly (P<0.01) affected Mg uptake of the sweet corn root. Highest fertilizer rate [150% (F4)] resulted in the highest Mg uptake (1.78 g $plant^{-1}$). Irrigation frequency significantly (P<0.05) influenced Mg uptake of the sweet corn root. Higher irrigation frequency (Ir1) had higher Mg uptake (1.54 g $plant^{-1}$) compared to other irrigation treatment. Fertilizer rate significantly (P<0.01) influenced Mg uptake of the sweet corn leaves. Higher fertilizer rate [150% (F4)] resulted in higher Mg uptake of the sweet corn leaves compared to other fertilizer rates. Irrigation frequencies did not affect Mg uptake by the sweet corn leaves. There were no significant interactions between irrigation frequencies and fertilizer rates on Mg uptake by the sweet corn leaves. Increase in Mg uptake of sweet corn roots and shoots resulted in the higher root and shoot biomass. This is reflected by the simple linear positive correlation between root dry weight and Mg uptake by the root (r=0.54, P<0.01) and between shoot total dry weight and Mg uptake by the leaves. This result is with agreement in that found by Abdulkadir [41].

Conclusions

The biomass and yield of sweet corn were influenced by irrigation frequencies and fertilizer rates. The yield of corn was increased with increase in irrigation frequencies. Irrigating corn at alternate days had resulted in good corn growth, which was translated into increased yield. This indicates the high demand of water during the growing period of the crop. Similarly, the yield of corn increased as fertilizer rate was increased, implying that the crop responded positively to increased fertilizer application. Hence, it is concluded that the fertilizer rate currently adopted in Malaysia for corn production needs to be revised upwards in order to meet its requirement for maximal productivity.

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