EFFECTS OF WATERLOGGING ON THE YIELD AND GROWTH PERFORMANCE OF GRAIN CORN UNDER FARM-SCALE PRODUCTION

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ABSTRACT

Flood and excessive rainfall every year in tropical rainforest climate affect annually during the monsoon season east and west coast in Malaysia. The most vulnerable sector could be affected is agriculture. An actual field planting experiment was monitored to study the effects of waterlogging for different conditions on the growth of grain corn at the well-drained condition (T1), waterlogged with draining after 24 hours condition(T2) and waterlogged condition (T3) during the northeast monsoon at MARDI Seberang Perai. Waterlogging affected delayed the development of flowering stages 5 to 7 days for the first flowering and cob development delayed in 3 to 5 days at the reproductive stages period. In term of flowering and cob development numbers, well-drained treatment showed high performance compared to another treatment. Yield component (cob numbers and cob weight) and plant morphology (plant height and cob height) significantly difference in between each treatment. The yield losses 73% due to waterlogging stress compared to well-drained condition. The yield of grain 50% improved by drain out of water after 24 hours field waterlogged. No significant difference existed between plants numbers and cob numbers. The grain moisture content showed slightly differences between each treatment. Grain corn was most waterlogging damage at T3(1.65 t/ha) followed by T2 with increasing field conditions (3.1 t/ha) and the well-drained condition showing susceptible growth and yield performance (6.23 t/ha).

Keywords: Yield, grain corn, waterlogging

INTRODUCTION

The failure of most grain corn production planting area in Malaysia is on excessive rainfall during the monsoon season, especially on the east coast cause the lowest in grain yield (Muhammad Haniff *et al*, 2020). The reason may be that rainfall is heavy, soil drainage is poor, the soil texture is heavy, and the land is not leveled (Tian et al., 2019). The planting season of grain corn in Malaysia is during the monsoon season were come twice a year. Utilizing the monsoon rainfall is the best practices to reduce cost on irrigation and operation (Ahmad M.H, et al, 2021). In South-East Asia alone, about 15% of the total maize growing areas are affected by floods and waterlogging problems (Baranw et al., 2002). Some part of China, the most rainfall occurs during the growing season of summer maize, and growth and yield of maize are significantly affected by farmland water storage (Ren et al., 2014). The effect of waterlogging on maize varies among cultivars, growth stages, environmental conditions, and waterlogging duration (Zubairi et al., 2012). The maize crop suffers badly whenever it encounters temporary waterlogged conditions during the monsoon season or grown in poorly drained converted paddy fields after the rainy season rice crop(Anthony Casilen Esteban et al., 2016)

MATERIAL AND METHOD

The field experiments were conducted at MARDI Seberang Perai in Penang, Malaysia, in end of September-November 2020. The test site has a tropical monsoon climate. The total rainfall exceeded 1000 mm during the northeast monsoon grain growth period (Fig. 1). The experimental soil type is a sandy loam. Soil fertility was measured before sowing. The cultivar hybrids grain corn P4546 from Pioneer DuPont was used as planting materials.

Cultural practices

Mechanization was applied during the land preparation. The activity of land preparation such as Plough, harrow and rotovating was applied before planting. Grain corn seeds were planted using a seeder implement at a planting density of 66,667 plants per hectare. The planting distance was 75 cm between rows and 20 cm between plants in plot size Pre-emergence herbicides for controlling weed were applied after planting. To ensure optimum growth of the plants, regular maintenance for pesticide and weeding was carried out during the plant growth. Observation of pest infestation was carried out daily in between 0-20 days after planting.

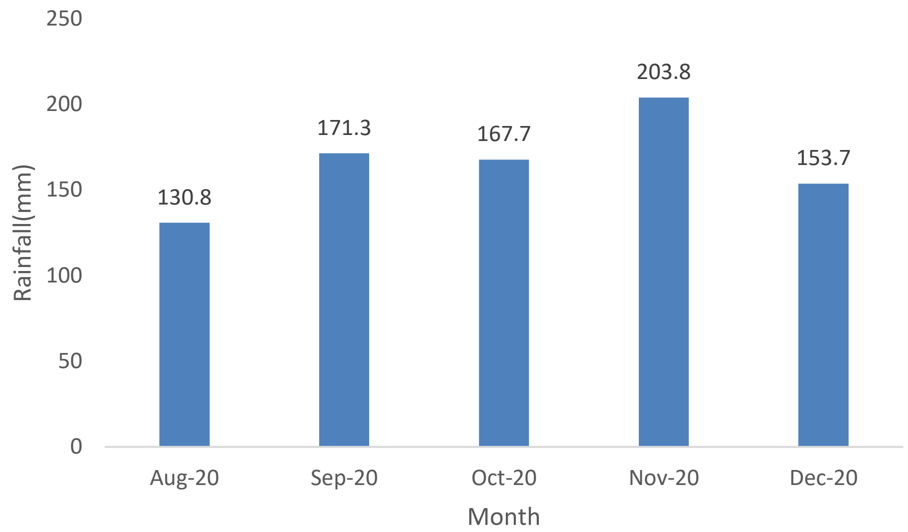
Table 1. Grain corn planting characteristic

Characteristic	Parameters	Description	Values
Location	Seberang Perai Utara, Penang	MARDI Seberang Perai	5.540598, 100.472822
Soil sample	pH	pH Meter	5.5
	Soil type	Holyrood	sandy loam
Mechanization	Land preparation	Ploughing	15 ~ 20 cm
		Harrowing	15 ~ 20 cm
		Rotovating	15 ~ 20 cm
	Seeding with fertilizer	Pneumatic seeder cum fertilizer	Seed rate 20 kg/ha NPK green fertilizer $15N:15P_2O_5:15K_2O$ 400 kg/ha
	spraying	High clearance tractor with boom spraying	Pre-emergence Pest control Liquid fertilizer
	Fertilizing	-	Urea, 130 kg/ha
Water source	Rainfall	Portable weather station (Davis instrument)	Millimeter, mm

Rainfall distribution at MARDI Seberang Perai

Northeast monsoon occurred annually in MARDI Seberang Perai started on September to November. The most intensity of rainfall happened during this period which average rainfall is around 150 mm monthly. The high rainfall rates during these months greatly influenced the results at the experimental test sites and crop growth performance. Rainfall measurements were taken using a portable rain gauge installed near the study plot. Adequate rainfall in this season does not require additional irrigation to support the water needs of grain corn plants. However, the high rains resulted the catastrophic floods where the study plots were filled with water in a short period of time and submerged the crops. Figure 1 below showed the rate of rainfall from the beginning of planting season until the harvest season. In September showed a relatively high rainfall rate affecting the performance of crops aged less than 30 days after planting.

Figure 1. Total monthly rainfall during monsoon-growing season at MARDI Seberang Perai, in 2020



Experimental design

The layout of the experimental plot was set up by randomize complete block design (RCBD) inside the planting area. This study was focusing on the actual field observation on the grain corn plantation. The randomize procedure to arrange the treatment of waterlogging effect infield by observation based on the condition affected by crop (Table 2). Comparisons among different treatments were based on LSD at the 0.05 probability level ($p<0.05$). Analysis was performed for grain yield and plant characteristics using SAS Statistic software(SAS Inc.). Experiments were tested in 3 treatments, the first treatment is the condition of the corn planting area that is in the water is completely drained, the second treatment is the condition of stagnant water is drained out after 24 hours and finally the planting condition is in a fully submerged condition. This treatment has 3 replications for each treatment. This study was conducted to find out the extent of performance of grain maize plants in stagnant water environment and factors that affect growth if there is a flood disaster during the monsoon season.

Table 2. Waterlogging treatments in the field

Treatment	Abreactions	Waterlogging period
Well-drained condition	T1	
Drain after 24 hours	T2	15 DAS – 30 DAS
Waterlogged condition	T3	

Growth performance

Five representative plant samples were obtained from each plot during waterlogging at the days 30, days 45(Tasselling stages), and days 110 harvesting period. The plant height was measure using the staffing measurement. Measuring from soil ground level to the last collar of corn leaves. Girth diameter was measuring using digital vernier calliper at 5 cm height from the ground level. The chlorophyll content index of the functional leaves was determined using a SPAD 502DL Plus portable chlorophyll meter (Spectrum technologies, Inc, U.S.A).

Accumulation of Flowering and cob development

The data of flowering development were recorded at 45 DAS. Cob establishment was recorded during the experiment from 45 DAS until 65 DAS. Flowering and cob establishment were monitored and recorded manually.

Yield components

Each plant cob sample was harvested manually. The following data were taken at sampling time using a standard ruler and weighing machine: number of plants, number of cobs within the crop cutting test (CCT) area which is 5 m x 3m (15 m^2) per plot. Grain yield is obtained from grain weight from the weight of the dry cob which is corrected for a percentage of 80% where the 20% was cob core weight and a moisture content of 14%. Moisture content is measured using the Agratronix MT-16 grain moisture tester.

$$\text{Adjusted weight at moisture content 14\%} = \frac{\text{W (100 \% - MC)}}{100\% - 14\%}$$

where, W = fresh weight, MC = Average moisture content(%)

RESULTS AND DISCUSSIONS

Plant morphology

Plant height

Ren et al., 2014 observed 3% to 8% of crop heights are stunted due to waterlogged. Table 3 showed the analysis of plant height was lowest with waterlogging, with showing lesser almost 50% at 30 DAS of T2 and T3 condition treatments respectively. The normal condition showed significantly on the height at 85.53 cm respectively. At 45 DAS, the plant height at T3 showed difference about 65% compared to T1 and T2 height was 53% lower than T1. By the harvesting period, the treatment showed slightly difference on T2 and T3, however for T1 height slightly higher about 28% compared to another treatments.

Stem Diameter

Previous studies described fibre type trees are also affected by the diameter of the crop stem depending on the time the crop sinks(Amri et al., 2014). From table 3 shows that waterlogging also affected the stem diameter of grain corn. At 30 DAS showing 51% differences in between the well-drained condition and waterlogging condition. In 45 DAS, waterlogging condition, T3 improved to 25% of stem diameter where T1 at 1.76 cm. In between T2 and T3, there showed no difference existed among both conditions. During the 110 DAS, stem diameter for T1 significantly higher compared to T2 and T3. All treatment almost same value from 45 DAS until the harvesting period.

Chlorophyll content

Studies showed, crop chlorophyll at 9 days and 15 days decreased due to stagnant water (Tian *et al*., 2019)Chlorophyll is one of the important physiological characteristics of plants, and it is also an indispensable material basis for photosynthesis of plants (Tian *et al*., 2019). Another research analysed decrease in leaf chlorophyll under waterlogging condition may also be directly related to nitrogen deficiency caused by leaching and de-nitrification of the applied nitrogen (Tsai *et al*., 1992).These studies proved waterlogging affected leave Chlorophyll content. Among the treatments, the chlorophyll parameters of T1 were greatest, whereas those in T2 and T3 were lowest at early vegetative stages 30 DAS and 45 DAS. From 30 DAS until 45 DAS, T2 and T3 slightly increased the chlorophyll content to 34.67 and 31.77 respectively compared to T1 which was significantly increase to 47.40 respectively. Chlorophyll content for all treatments dropped at the maturity stages and showed no significant differences during the harvesting at 110 DAS.

Table 3. Effect of waterlogging condition on plant height, chlorophyll content, and stem diameter

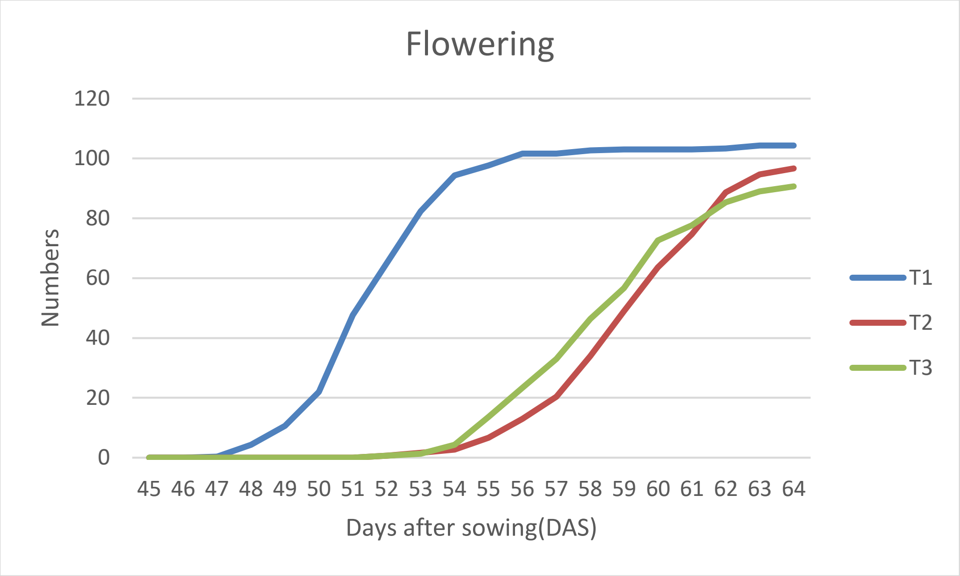
	Plant height(cm)			Stem diameter(cm)			chlorophyll content (%)		
	30 das	45 das	110 das	30 das	45 das	110 das	30 das	45 das	110 das
Waterlogged condition	**	**	ns	**	*	*	**	*	ns
Well-drained condition	85.53a	173.23a	200.27a	1.45a	1.76a	1.71a	41.20a	47.40a	10.53a
Drain after 24 hours	36.10b	80.67b	143.47a	0.75b	1.37b	1.31b	31.07b	34.67b	13.67a
Waterlogged condition	37.27b	59.60b	144.60a	0.77b	1.31b	1.10b	29.47b	31.77b	9.33a

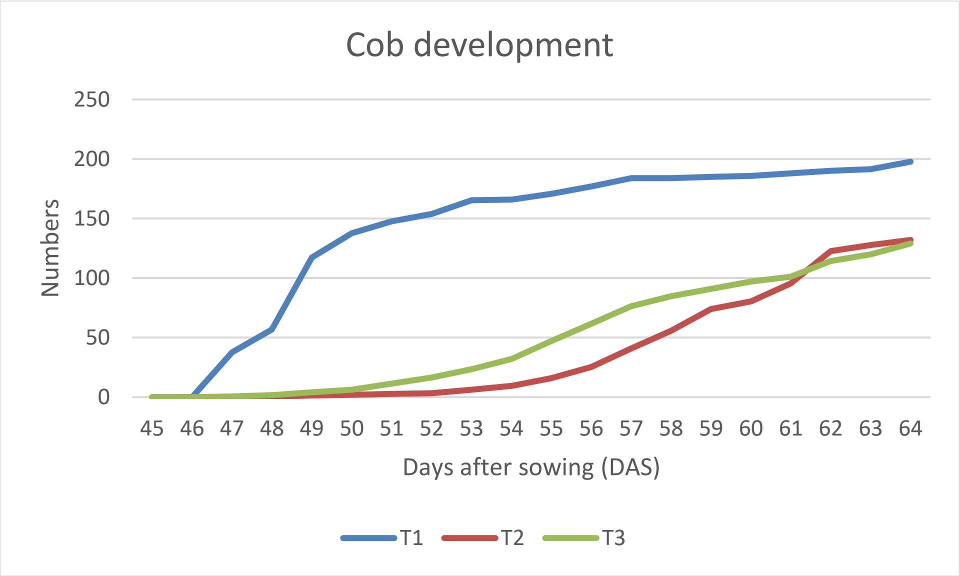
Note : **Significant at 1% probability level, *Significant at 5% probability level, ns: Not significant. Means in each column with the different letters within each factor indicate significant differences at P≤0.05% level according to LSD.

Flowering and Cob development accumulation

Among the parameters that contribute to the yield is the pollination stage. During this stage, production of grain corn yield estimates can be evaluated(Gerpacio *et al*.,2007).The effects of waterlogging on flowering accumulation were similar between the T2 and T3, but no effect on T1 where the condition was well-drained. The negative effects of waterlogging delayed the flowering for T2 and T3. At T1, the crop starts to develop flowering as early 46 DAS where T2 and T3 began at after 50 DAS. Flowerings for T1 accumulation were rose significantly from 0 to above 100 numbers within a week. Compared to T2 and T3, the delaying processed to produce the flowers end at 63 DAS. Waterlogging affected cop numbers (Figure 2). Among the treatments, the cob development parameters of T1 were greatest, whereas those in T3 was the lowest. Total days of cob development for T1 in 18 days period respectively, which maximum numbers of cob was 198 developed, while for T3 the duration of cob development were ranges 9 days to 17 days which were 34% reduction of number of cobs to nearly 130. A similar tendency was observed in T2.

Figure 2. Effects of waterlogging on flowering and cob developments accumulation of grain corn





Grain yield

Grain corn yield losses with waterlogging for more than 3 day by over 40% ,grain yield by 20-35% after waterlogging(Ren *et al.*, 2014). Some reports have stated the loss of yield was estimated to be between 30% to 50% due to waterlogged conditions on a small experimental scale). From these study, yield significantly loss with affected by waterlogging at farm scale condition. From the table 3 below, these results indicate that the cultivar responded to waterlogging, and were most susceptible to damage at T3, followed by T2 and T1 grain yields in treatments. The yield losses 73% due to waterlogging stress compared to well-drained condition. The yield 50% improved by drain out of water after 24 hours field waterlogged. No significant difference existed between plants numbers and cob numbers. The grain moisture content showed slightly differences between each treatment.

Table 3. Effect of waterlogging on grain corn yield

	Plants numbers	Cob numbers	Cob weight (kg)	Grain moisture content (%)	Yield (t ha^{-1})
Waterlogged condition	ns	ns	*	ns	*
Well-drained condition	104.33a	99.67	13.67a	26.77a	6.23a
Drain after 24 hours	88.33a	87.33	6.87b	27.27a	3.10b
Waterlogged	97.67a	88.33	3.67c	28.00a	1.65c

Note : **Significant at 1% probability level, *Significant at 5% probability level, ns: Not significant. Means in each column with the different letters within each factor indicate significant differences at P≤0.05% level

CONCLUSIONS

The challenge in field mechanization grain corn planting during the monsoon seasons showed the substantial reduction of grain corn yield because of waterlogging due to poor land levelling and drainage system, especially for the new planting area or new farmer in the industry. The study proved that grain corn is sensitive to the waterlogging. Early stages of waterlogging occur to the field stunted the growth of grain corn characteristic such as plant height, stem diameter, and chlorophyll content. From an observation, reduction of above 50% of crop growth will reduce the yield of grain corn. In term of flowering, most of the crop affected by waterlogged delay the pollination and tasseling stages. Compared to normal condition, planting area affected by waterlogged delay nearly 5 days for pollinations occurrence at 53 DAS where the normal condition is 47 DAS. Results showed that the numbers of flowering lesser compared to the non-waterlogging area. At present, some farmland management measures are used to alleviate the damage of waterlogging, mainly including construction of farmland drainage facilities, improvement of farming methods, improve the water management system and selection of waterlogging-resistant varieties.

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