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Growth and Yield of Selected Forage Corn Hybrids and Weed Composition under Different Fertilizer Application Regimes

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ABSTRACT

Key focus for improving fertilizer use efficiency and increasing corn productivity is timing of fertilizer application at suitable crop growth stage. Therefore, a field research was conducted during 2019, at Field 15, Faculty of Agriculture, University Putra Malaysia, to quantify the effect of four fertilizer application regimes T_1 (1, 3 and 4 weeks after planting–WAP), T_2 (2, 4 and 6 WAP), T_3 (2, 4, 6 and 8 WAP) and T_4 (2, 4, 8 and 10 WAP) on growth and yield attributes of two corn varieties (GWG888 and CP888) and weed composition. The results indicated that both factors (fertilizer application regimes and varieties) significantly influenced corn growth, yield and weed composition. It was observed that T_3 (application of fertilizer at 2, 4, 6 and 8 WAP) for GWG corn variety produced the highest plant height, leaf area, cob length, dry matter yield and crude protein, while it decreased NDF, ADF and lignin content compared to other treatments. Meanwhile, broad leaf weeds showed higher dominance in all fertilizer application regimes compared to grasses and sedges weed. The findings suggested that the use of fertilizer up to 8 WAP resulted in sufficient nutrients supply for flowering and after flowering stages, which improved corn growth, yield and forage quality.

Key words : Forage corn, weeds, fertilizer application regimes, growth, yield

INTRODUCTION

Corn is the world's oldest and most commonly grown cereal. For growth and high grain yield, it needs sufficient soil fertility. Generally, corn is conventionally cultivated with heavy use of inorganic fertilizer (Brotodjojo and Arbiwati, 2018). Besides, the optimal application time of fertilizer to crop enables sufficient supply during maximum uptake and critical growth stages (Bindraban *et al*., 2015). Timing of fertilizer application plays a key role in decreasing nutrient losses to the environment by providing supply when crop demand is high. Consideration of timing is generally site-specific, it is hence influenced by local environmental conditions and the abilities of the former in management practices (Johnston and Bruulsema, 2014). Though the management of nutrients is a complicated process, our understanding of timing and rates of uptake improve, the reconfiguration and remobilization of nutrients by corn plant create opportunities to optimize fertilizer levels, source and timing of application. Dissimilar with other nutrients, the concentrations of P, S and Zn were superior during grain filling than vegetative growth; therefore, seasonal supply is essential for balanced crop nutrition.

During vegetative development stages, an adequate N supply is essential, but generally, less than 40% of vegetative N is removable to support grain production. The availability of late-season N is also important in high yield situations where the grain N demand approaches 200 lbs N/acre. Depending on these research results, a logical approach is to develop a plan for the application of N that represents crop demand to minimize losses and optimize N uptake (Debruin and Butzen, 2014). Furthermore, effective management of fertilizer is essential to ensure maximum economic yield and to increase nutrient use efficiency. This can be partly documented to inappropriate management of N which includes both N overuse than their required

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rate and inappropriate application time of N (Liu *et al.*, 2015). Compared to conventional broadcast fertilization, application of fertilizer in a row or row fertilization combined with top dressing increased N fertilizer percentage in total N uptake and the agriculture and physiological efficacy of N use (Szulc *et al.*, 2016). Study has documented in recent years that modern hybrids take up further post-flowering N compared with older hybrids. The N uptake timing also becomes a deciding factor in corn yield, in which newer hybrids have taken up 29% more N post-flowering than older hybrids (Nasielski *et al.*, 2019).

The uptake rate of nutrients as the corn plant develops is influenced by weather, date of planting, and fertilizer application time but, in general, the highest uptake occurred between V8 and silking. Since the applications of N fertilizer were delayed until V16, the maximum uptake rate of N was usually delayed until after silking. Fertilizer improves soil fertility and hence affects weed density, uptake of nutrient and biomass yield, which in sequence impacts the composition and biodiversity of species (Tang *et al.*, 2014). Fertilizer application should be at a suitable time, so that weed emergence and infestation can be checked to improve crop production by maximizing the use of nutrients. Thus, to increase corn production and manage weeds, proper fertilizer application regimes are essential. Although, there is lacking studies on proper fertilizer application regimes in corn, especially forage corn in Malaysia, there is a need to determine optimum fertilizer application regime for corn. Therefore, the current study was conducted to investigate the effect of fertilizer application regimes on weed composition, and growth and yield of two different corn varieties.

MATERIALS AND METHODS

A field experiment was conducted during 2019 at Field 15, Faculty of Agriculture, University Putra Malaysia in Serdang, Selangor to investigate the effect of fertilizer application regimes on growth, yield and weed composition of two different corn varieties. The region lied between 2°59′ N latitude and 101°44′ E longitudes with an elevation of 52 m from the sea level. Two forage corn varieties, namely, new hybrid (GWG888) and old hybrid (CP888) were chosen. Both varieties were obtained from Thailand, and commercialized by the Green World Genetics Sdn. Bhd.

The experimental site was ploughed mechanically prior to seed sowing. Soil samples were randomly taken to a depth of 15 cm using auger from the plots (approximately 10 sample points) for pH analysis. As the pH was below 5, liming was performed at the rate of 2 t/ha two weeks before corn seeds sowing. The soil was then rotovated to achieve an adequate size for planting. A total of two seeds were planted per hill at 20 x 75 cm planting density. Later seedlings were thinned to a single plant per hill, to produce a total of 66667 plants per hectare. Each sub-plot consisted of four rows, separated by 35 cm inter row and 50 cm buffer zone between sub-plots. The plots were irrigated using overhead sprinkler irrigation system. Depending on the rainfall distribution, the system was switched once or twice daily, especially in the morning and late afternoon.

The experiment was established with three replications in a split-plot design, comprising four intervals of fertilizer application regimes as the main plot and two varieties of corn as the subplot. The area of each sub-plot was 3.65 x 4 m, while the total area used for the experiment was 39 x 14.6 m. The four fertilizer application regimes chosen were T_1 (1, 3 and 4 WAP), T_2 (2, 4 and 6 WAP), T_3 (2, 4, 6 and 8 WAP) and T_4 (2, 4. 8 and 10 WAP). Three types of chemical fertilizers were applied to the corn plants : NPK green fertilizer, NPK blue fertilizer and urea, yielding a total amount of fertilizer 140 kg N/ha, 100 kg P/ha and 120 kg K/ha, which was the standard rate for corn planting in Malaysia.

Observation on growth parameters was made at two middle rows to prevent border effects from nearby plots. The field data were collected at 4, 6, 8, 10 and 12 weeks after planting. Plant height, number of leaves, chlorophyll content, leaf area, cob number, cob length, and the dry weight of leaves, stem, cob and total plants were measured using standard ruler, digital balance, Minolta SPAD 502 Chlorophyll, Japan, and LI-3100 Area Meter. At 13 WAP, all corn plants were harvested above ground for nutrients and quality analysis. Plant parts were then dried on the oven until the weight was constant. The dry weight of leaves, stem, cob and total plants was measured. Then, the dried samples were ground and placed in pill boxes for further analysis. The concentration crude protein (CP) was calculated by the multiplication of N concentration to a value of 6.25. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were calculated using the FOSS Fiber Cap 2023 Process (FOSS Analytical AB, Hoganas, Sweden; Nazli *et al.*, 2019), while the same ISO method was used for lignin analysis, by using FOSS M6 1020/1021 Fibertec system (FOSS, Hilleroed, Denmark; Nazli *et al.*, 2019). The weed composition was determined at 12 weeks after sowing using three quadrates in each plot. All weeds present in quadrate were collected, sorted, counted by species and converted to number/m^2. The important value (IV) was a numerical parameter that indicated the relative importance of each species within population. The below formula was used for calculating the important value (Numbere, 2020).

IV = Relative density + Relative frequency + Relative dominance

$$\text{Relative density (\%)} = \frac{\text{Number of individuals of species}}{\text{Total number of individuals}} \times 100$$

$$\text{Relative frequency (\%)} = \frac{\text{Frequency of species}}{\text{Total number of species}} \times 100$$

$$\text{Relative domiance (\%)} = \frac{\text{Total area of species}}{\text{Area of all species}} \times 100$$

Analysis of variance (ANOVA) was used to determine the effect of treatment, while treatment means were compared with least significance difference (LSD) at P<0.05 using SAS software (9.4 version, SAS Institute Inc., North Carolina 27513, USA).

RESULTS AND DISCUSSION

Fertilizer application regimes and varieties significantly influenced the plant height, number of leaves, chlorophyll content, leaf area, cob number, cob length (Table 1). T_3 (2, 4, 6 and 8 WAP) produced the highest plant height, number of leaves, chlorophyll content, leaf area and cob length followed by T_2 (2, 4 and 6 WAP), while the least was observed in T_1 (1, 3 and 4 WAP). Higher plant growth attributes were observed in new corn variety (GWG888) compared to old corn variety (CP888). In general, corn growth was highest with the application of fertilizer at 2, 4, 6, and 8 WAP (T_3). It was due to the supply of maximum nutrients in both vegetative and reproductive stages which matched corn nutritional needs. The new hybrid corn variety GWG888 produced higher plant height in T_3 compared to the old hybrid CP888. The nutrient use efficiency of a new hybrid was higher which caused increase in plant production. Research showed that a new hybrid took more N post-flowering compared to the old hybrid (Nasielski *et al.*, 2019). Due to sufficient availability of nutrients and highest plant height, the numbers of leaves were highest in T_3 compared to other treatments. The numbers of leaves were not significantly different among the varieties because of genetic and environmental effects. T_3 produced the largest leaf area in the new

Table 1. Effect of fertilizer application regimes and corn varieties on plant height, number of leaves, leaf area, cob number and cob length

Treatment	Plant height (cm)	No. of leaves	Leaf area (cm^2)	Cob number	Cob length (cm)
Fertilizer application regimes					
T_1	182.51c	11.56b	2304.65c	1.16a	16.3b
T_2	185.06b	11.98ab	2428.44b	1.2a	16.32b
T_3	193.75a	12.43a	2650.25a	1.21a	20.9a
T_4	181.36c	11.83ab	2228.07c	1.15a	16.1b
Variety					
GWG888	189.38a	12.02a	2419.03a	1.19a	18.41a
CP888	181.96b	11.88a	2386.67b	1.17a	16.5b

Means within columns with different letters significantly differ at LSD=P≤0.05). T_1–Fertilizer application at 1, 3, and 4 WAP, T_2–Fertilizer application at 2, 4 and 6 WAP, T_3–Fertilizer application at 2, 4, 6 and 8 WAP and T_4–Fertilizer application at 2, 4, 8 and 10 WAP. WAP–Weeks after planting.

corn variety. Effective use of nutrient and maximum number of leaves in T_3 (2, 4, 6 and 8 WAP) had significant effects on the vegetative growth which increased the corn leaf area. Proper supply of fertilizer enhanced the number of leaves which consequently increased leaf area. The numbers of cobs were not significantly influenced by fertilizer application regimes and corn varieties. This was due to the genetic characteristics of both varieties that most of plants produced one cob per plant. Fertilizer application regimes and varieties significantly affected the cob length compared to other treatments. T_3 produced the highest cob length. This was due to adequate availability of fertilizer at cob development stages which led to increased cob length. Debruin and Butzen (2014) reported that application of fertilizer till tasseling stage (8 WAP) provided sufficient nutrients in the reproductive stage, which improved the length of cob.

The DM yields of leaves, stem, cob and total plant were significantly affected by fertilizer application regimes and corn varieties (Table 2). Regardless of variety, leaves, stem, cob and total DM yield were the highest in T_3 (2, 4, 6 and 8 WAP) followed by T_2 (2, 4 and 6 WAP) and T_4 (2, 4, 8 and 10 WAP), while the lowest was observed in T_1 (1, 3 and 4 WAP). Similarly, yield attributes in the new corn variety GWG888 recorded higher value over the old corn variety CP888. The maximum leaves DM yield in T_3 was attributed to the highest leaf area and number of leaves, while the highest stem DM yield was due to maximum plant height and greatest stem girth. The sufficient supply of nutrients supported the corn plant to improve its plant growth by developing more leaves per plant and higher leaf areas, resulting in more photosynthesis, thus leading to higher production of dry matter (Moe *et al.*, 2019). The increased cob DM yield in T_3 was due to producing the longest cob and highest cob FM yield. The highest total DM yield in T_3 was due to sufficient and effective use of nutrients which increased overall plant growth and it contributed to produce the highest total DM yield. Canatoy (2018) reported that, for achieving higher DM yield, there must be suitable amount of nutrients available in the soil which later became part of the growing corn dry matter by processing these nutrients into other essential components of the corn plant. The greater DM production in the variety of GWG was due to better genetic characteristics compared to CP variety, which caused increased nutrients uptake and consequently enhanced DM yield.

Fertilizer application regimes significantly affected crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin content of leaves, stem, cob and total plant (Table 3). There were significant differences detected between varieties in the term of CP, NDF and lignin, while ADF was not significantly different among the varieties. Fertilizer application regime of T_3 (2, 4, 6 and 8 WAP) significantly increased CP, while it decreased the content of ADF, NDF and lignin at all corn parts. The highest amount of ADF, NDF and lignin and the lowest amount of CP was observed in T_1 (1, 3 and 4 WAP). The highest CP content was measured in leaves followed by cob and it was the lowest at stem. While NDF (%) was higher in corn cob and stem compared to stem. The content of ADF was highest in stem followed by cob and the lowest was obtained in leaves. Leaves and stem yielded more lignin content than corn cob. Compared to old corn variety (CP888), new corn

Table 2. Effect of fertilizer application regimes and corn varieties on leaf, stem, cob and total plant dry matter yield (t/ha)

Treatment	Leaf DM yield (t/ha)	Stem DM yield (t/ha)	Cob DM yield (t/ha)	Total DM yield (t/ha)
Fertilizer application regimes				
T_1	2.85b	4.94b	13.08c	21.77c
T_2	3.03ab	5.12b	14.61b	22.7b
T_3	3.37a	5.8a	16.23a	24.03a
T_4	3.01b	4.8b	13.27c	20.49d
Variety				
GWG888	3.54a	5.44a	14.72a	22.51a
CP888	2.68b	4.89b	13.87b	21.97b

Means within columns with different letters significantly differ at LSD=P≤0.05). T_1–Fertilizer application at 1, 3, and 4 WAP, T_2–Fertilizer application at 2, 4 and 6 WAP, T_3–Fertilizer application at 2, 4, 6 and 8 WAP and T_4–Fertilizer application at 2, 4, 8 and 10 WAP. WAP–Weeks after planting.

Table 3. CP, NDF, ADF and lignin (%) of leaf, stem, cob and total plant as influenced by fertilizer application regimes and corn varieties

Treatment	Leaf CP (%)	Stem CP (%)	Cob CP (%)	Total CP (%)
Fertilizer application regimes		**CP (%)**		
T_1	12.43b	11.04b	11.67b	11.81b
T_2	13.36ab	11.61ab	12.56ab	13.05ab
T_3	14.92a	12.49a	13.31a	13.63a
T_4	13.58ab	11.74ab	12.63ab	13.14ab
Variety				
GWG888	13.78a	11.94a	13.05a	13.39a
CP888	13.36b	11.5a	12.03	12.42b

NDF (%)

Treatment	Leaf NDF (%)	Stem NDF (%)	Cob NDF (%)	Total NDF (%)
Fertilizer application regimes				
T_1	54.09a	69.18a	73.07a	61.94a
T_2	48.15ab	67.97a	66.84b	61.27ab
T_3	41.93b	60.52b	61.28c	55.36b
T_4	46.16b	64.73ab	64.37bc	60.1ab
Variety				
GWG888	45.86a	63.82a	64.21a	56.48b
CP888	49.3a	67.38a	68.21a	62.85a

ADF (%)

Treatment	Leaf ADF (%)	Stem ADF (%)	Cob ADF (%)	Total ADF (%)
Fertilizer application regimes				
T_1	42.69a	56.54a	49.42a	49.85a
T_2	38.09ab	48.79b	35.08b	43.84ab
T_3	33.11b	38.24c	26.52b	35.96b
T_4	35.55b	47.9b	32.7b	39.9b
Variety				
GWG888	36.09a	47.06a	32.34a	40.67a
CP888	38.68a	48.67a	39.52a	44.11a

Lignin (%)

Treatment	Leaf lignin (%)	Stem lignin (%)	Cob lignin (%)	Total lignin (%)
Fertilizer application regimes				
T_1	7.54a	7.4a	5.9a	7.16a
T_2	7.35a	5.37b	5.23ab	6.54a
T_3	6.51a	5.05b	4.84b	4.69b
T_4	7.5a	5.33b	4.89ab	5.94ab
Variety				
GWG888	6.82b	4.99b	5.13a	5.76b
CP888	7.63a	6.58a	5.29a	6.4a

Means within columns with different letters significantly differ at LSD=P≤0.05). T_1–Fertilizer application at 1, 3, and 4 WAP, T_2–Fertilizer application at 2, 4 and 6 WAP, T_3–Fertilizer application at 2, 4, 6 and 8 WAP and T_4–Fertilizer application at 2, 4, 8 and 10 WAP. WAP–Weeks after planting.

variety (GWG888) had greater amount of CP and less amount of ADF, NDF and lignin in corn leaves, stem, cob and total plant. Fertilizers, particularly N are important factors that influence the chemical composition of corn plant. In the current study, the forage nutritional quality improved with application of fertilizer until tassel stage. The highest CP content in T_3 was due to enhanced N uptake, which led to increased CP content in corn plant. An increase in the percentage of CP with enhanced N uptake attributed to N being a main component of protein structure. Crude protein was one of the most essential nutritional compounds in animal feeding and its reduction in forage decreased livestock yields (Lamptey *et al.*, 2018). Fertilizer application regime of T_3 significanlty decreased the NDF, ADF and lignin content. This was due to an increase in CP and other soluble content that accumulated in the cell and caused cell wall dilution. The reduction in NDF and ADF content with an increase in the supply of nutrients might be due to a higher amount of nutrients resulting in synthesized carbohydrates that were rapidly converted into proteins and protoplasm. The reduction in lignin content might be due to sufficient nutrition which caused to enhance protein formation and led to decrease lignin content.

Fourteen species of weed including all the main three weed classes (Broad-leaved, grasses and sedges) were obtained in the plots fertilized with four fertilizer application regimes in GWG corn variety (Table 4). Generally, weed composition in all fertilizer application regimes was probably similar, wherever broad-leaved displayed greater dominance compared to grasses and sedges. The weed composition in fertilizer application regimes T_1, T_3, and T_4 were greatly dominated by *Borreria latifolia* with I. V. value of 27.41, 31.03 and 21.05, respectively. *Ageratum houstonianum* and *Croton hirtus* also largely dominated in T_1, T_3 and T_4 fertilizer application regimes. In fertilizer application regimes T_2 *Ageratum houstonianum, Calopogonium mucunoides* and *Mimosa pudica* were the highest among all weed species. The I. V. values for *Digitaria ciliaris* and *Digitaria fuscescens* were 9.67 and 4.87 in T_1, respectively, while in T_3. *Ipomoea triloba* was less dominated in T_1, T_3 and T_4 but it was restricted in T_2. Meanwhile, *Asystasia gangetica* was quite dominant in T_1, T_2 and T_4 with the I. V. values of 8.06, 5.47 and 3.11 in each treatment, respectively, but it was limited in T_3. The composition of sedges (*Cyperus iria*) was the lowest among all fertilizer application regimes with the I. V. value of 1.36 and 2.59 in T_2 and T_3, respectively.

Fourteen species of weed included all the main three weed classes (Broad-leaved, grasses and sedges) were observed in the plots fertilized with four fertilizer application regimes in CP corn variety (Table 5). Compared to other weed groups broad-leaved were highly dominant, overgrown both grasses and sedges across all fertilizer application regimes. *Ageratum houstonianum* was the most dominant weed species in T_1 and T_3 fertilizer application regimes with I. V. values of 33.33 and 28.57, respectively. In T_2 and T_4 *Borreria latifolia* was the most prevalent species with the I. V. values of 22.05 and 23.52 in each treatment, respectively. *Croton hirtus* was noted dominated in T_1, T_2, T_3 and T_4, while *Calopogonium mucunoides* was prevalent in T_1 and T_2. Meanwhile, the number of *Digitaria fuscescens* was also high in all fertilizer application regimes with the I. V. value of T_1 (7.93), T_2 (8.82), T_3 (7.79) and T_4 (7.14), while *Digitaria ciliaris* was restricted in all fertilizer application regimes. *Ageratum conyzoides* was less dominant in T_1 and T_4 but it was limited in T_2 and T_3. Besides, *Mimosa pudica* was fairly dominant in all fertilizer application regimes with I. V. values of T_1 (6.34), T_2 (10.29), T_3 (7.79) and T_4 (5.95). Compared to other weed species *Cyperus iria* was highly restricted in all fertilizer application regimes. The composition of weeds in the field can be influenced by

Table 4. Total weed composition calculated by I. V. value (%) in GWG corn variety as influenced by fertilizer application regimes

Weed group	Weed species	Fertilizer application regimes			
		T_1	T_2	T_3	T_4
Broad-leaved	*Ageratum houstonianum*	12.67	39.72	12.62	18.93
	Mimosa pudica	6.45	9.58	5.78	5.26
	Croton hirtus	11.29	6.84	14.19	14.73
	Calopogonium mucunoides	9.90	10.95	4.28	4.21
	Borreria latifolia	27.41	8.21	31.03	21.05
	Crotalaria mucronata	0.00	2.73	0.00	5.26
	Amaranthus viridis	3.22	6.84	3.78	3.11
	Ipomoea triloba	6.45	0.00	5.45	6.11
	Asystasia gangetica	8.06	5.47	0.00	3.11
	Ageratum conyzoides	0.00	0.00	5.34	4.75
	Euphorbia heterophylla	0.00	4.10	0.00	7.36
Grasses	*Digitaria ciliaris*	9.67	0.00	8.04	0.00
	Digitaria fuscescens	4.87	4.10	6.89	6.11
Sedges	*Cyperus iria*	0.00	1.36	2.59	0.00

T_1–Fertilizer application at 1, 3 and 4 WAP, T_2–Fertilizer application at 2, 4 and 6 WAP, T_3–Fertilizer application at 2, 4. 6 and 8 WAP and T_4–Fertilizer application at 2, 4, 8 and 10 WAP. WAP–Weeks after planting.

Table 5. Total weed composition calculated by I. V. value (%) in CP corn variety as influenced by fertilizer application regimes

Weed group	Weed species	Fertilizer application regimes			
		T_1	T_2	T_3	T_4
Broad-leaved	*Ageratum houstonianum*	33.33	13.23	28.57	16.66
	Mimosa pudica	6.34	10.29	7.79	5.95
	Croton hirtus	7.93	14.7	9.09	9.52
	Calopogonium mucunoides	9.52	11.76	1.29	4.76
	Borreria latifolia	12.69	22.05	22.07	23.52
	Crotalaria mucronata	3.17	0.00	5.19	0.00
	Amaranthus viridis	4.76	4.41	6.49	3.57
	Ipomoea triloba	0.00	3.47	3.93	5.95
	Asystasia gangetica	0.00	0.00	5.19	8.33
	Ageratum conyzoides	6.34	2.97	0.00	7.45
	Euphorbia heterophylla	7.98	5.88	0.00	5.57
Grasses	*Digitaria ciliaris*	0.00	2.41	2.59	0.00
	Digitaria fuscescens	7.93	8.82	7.79	7.14
Sedges	*Cyperus iria*	0.00	0.00	0.00	1.57

T_1–Fertilizer application at 1, 3 and 4 WAP, T_2–Fertilizer application at 2, 4 and 6 WAP, T_3–Fertilizer application at 2, 4. 6 and 8 WAP and T_4–Fertilizer application at 2, 4, 8 and 10 WAP. WAP–Weeks after planting.

fertilizer application regimes. Fertilization affected soil fertility and hence influenced weed growth, nutrient uptake, and biomass production, which consequently affected the composition and biodiversity of species. Fertilizer indirectly affected weed composition by impacting nutrient competition and emission competition among plants and weeds (Tang *et al*., 2014), Broad-leaved achieved its full growth and became the dominant species. Broad-leaved had the highest relative rate of growth compared to other weed groups.

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