RESULTS AND DISCUSSION

1. PLANT GROWTH REGULATORS

I. GA_3 and CCC Experiment

Effect of GA_3 and CCC on vegetative growth parameters

There were no significant differences in any of the measured growth parameters of corn at the 5% level of significance in 1988 (Table 5). However, in 1989, the treatments significantly affected ear height, active leaf number, and percentage of barren plants. Cycocel at 300 ppm caused a greater increase in ear height than GA_3 at 75 ppm. There were no significant differences in ear height between GA_3 at 75 and 150 ppm or between CCC at 300 and 600 ppm, or between all PGR treatments and the check plots.

Active leaf number was significantly increased by application of either GA_3 at 75 ppm or CCC at 600 ppm, yet GA_3 at the higher rate and CCC at the lower rate did not cause any significant differences compared to the control. Only CCC at 600 ppm significantly increased the percentage of barren plants over GA_3 at 150 ppm.

From these data one can conclude that changing application rates of GA_3 and CCC had no significant effect on any of the major growth parameters. The lack of significance in 1988 and the small significant differences in 1989 may be due to the relatively high rates used in 1988 or because soaking the seeds in PGR solutions may not be the proper method under the conditions of this experiment.

Table 5. **Vegetative growth parameters of corn as influenced by a seed pre-treatment of gibberellic acid (GA_3) and cycocel (CCC) in 1988 and 1989 seasons.**

PGR rate (ppm)	Plant ht cm	Ear ht cm	Stem diam mm	Active leaf no.	LA cm^2	Days to mid-silk. no.	Barren plants %	Lodged plants %
				1988				
Check 0	252	117	19	11.1	615	56.7	9.6	21.8
GA3 150	245	110	19	11	625	56.7	9.1	19.6
GA3 300	245	109	19	11.1	612	56.8	7.8	20.6
CCC 600	251	118	18	11	629	56.8	10.8	29.5
CCC 1200	250	114	19	11.2	633	57.2	7.6	20.2
	NS	NS	NS	NS	NS	NS	NS	NS
				1989				
Check 0	258	111 ab *	17	9.9 a	621	66.8	8.3 ab	11
GA3 75	246	104 b	18	11.1 b	635	65.9	7.3 ab	12.4
GA3 150	251	110 ab	17	10.5 ab	613	66.6	6.7 b	12.9
CCC 300	251	112 a	17	10.4 ab	648	66.3	7.2 ab	10.3
CCC 600	253	108 ab	17	11.1 b	613	66.2	8.6 a	12.6
	NS		NS		NS	NS		NS

* Means for each parameter followed by the same letter are not significantly different at the 0.05 level.
NS = not significant at the 0.05 level.

Similar results for GA_3 were obtained by Koter *et al.* (1983). They applied GA_3 either when the maize plant was 15 cm tall or a split application at the 15 cm height and again at the beginning of plant flowering. Effects of these two GA_3 treatments were compared with the control which did not receive any PGR. They found no significant differences between GA_3 treatments compared to the control in any of the measured parameters such as plant height, ear height, or number and thickness of internodes.

Similar results for sorghum plant height and lodging as affected by GA_3 seed treatment were also reported by Gardner and Kasperbauer (1961). However, the findings of El-Deepah *et al.* (1989) were in disagreement with these results. Because they used a less soaking time (12 h), and different GA_3 concentrations; this might have been the reasons for this contrast.

Effect of GA_3 and CCC on yield, yield components, and grain N uptake

The PGRs had no significant effect on grain yield, stover yield (only estimated in 1989), or grain N uptake in either year of the experiment (Table 6). Four of five PGR treatments in 1988 and all PGR treatments in 1989 had no significant effect on the population of undamaged plants per unit area at harvest. The treatment of CCC at 1200 ppm in 1988 significantly reduced the population by 6,000 plants/fa compared to the check plots. It was observed that the application of CCC at the 1200 ppm rate had a deleterious effect on maize emergence, and resulted in much lower plant population compared to GA_3 treatments or the control.

In 1988, there were significantly fewer ears per plant in the 600 ppm CCC treatment than the 1200 ppm CCC treatment with no significant

Table 6. Yield, yield components and grain quality as influenced by a seed pre-treatment of gibberellic acid (GA_3) and cycocel (CCC) in the 1988 and 1989 growing seasons.

PGR	rate (ppm)	Populat-ion/fa no	Ear/plant no	Kernel/ear no	Wt ear kernels g	Wt/100 kernel g	Grain yield kg/fa	Grain N %	Grain N uptake kg/fa	Stover yield kg/fa
					1988					
Check	0	17,500 a *	0.83 ab	507 a	140.6 ab	32.6	2,600	1.75	46.2	---
GA3	150	16,500 a	0.89 ab	499 a	136.8 ab	34.3	2,700	1.72	46.4	---
GA3	300	15,200 a	0.87 ab	500 a	147.8 a	33.5	2,600	1.86	48.9	---
CCC	600	18,600 a	0.79 b	457 b	130.6 b	33.1	2,600	1.74	45.9	---
CCC	1200	11,500 b	0.95 a	488 a	145.4 a	33.7	2,300	1.86	43.5	---
						NS	NS	NS	NS	
					1989					
Check	0	19,000	0.94 a	493	154.1	32.2	2,300	1.71	40	2,800
GA3	75	19,100	0.97 ab	496	163.8	33.3	2,500	1.68	42	3,000
GA3	150	19,300	1.01 b	499	161.5	32.8	2,500	1.65	40.9	2,900
CCC	300	20,300	0.94 a	483	153.9	33.5	2,400	1.69	41.3	3,200
CCC	600	19,300	0.97 ab	494	161.5	34.7	2,400	1.65	39.3	2,900
		NS		NS	NS	NS	NS	NS	NS	NS

* Means for each parameter within year followed by the same letter are not significantly different at the 0.05 level.
NS = not significant at the 0.05 level.

differences among other treatments. The greater ear number on the high CCC rate treatment was likely due to the lower plant population in this treatment.

In 1989, plants treated with GA_3 at 150 ppm had the highest number of ears per plant. This result was only significant when compared to the control or CCC at 300 ppm treatments. It appears from these data that the application of CCC at 600 ppm in 1988 or at 300 ppm in 1989 negatively affected ear characteristics. In general, although the GA_3 combinations had a slight, non significant positive effects on grain yield and the CCC had a deleterious impact on the number of plants at harvest, there was no clear trend of the effects of the two PGRs on the measured parameters in table (6).

Effect of N rates on vegetative growth parameters

The N rate treatments resulted in no significant differences in any of the measured parameters in 1988, so those results are not presented here in this text. This probably was due to the late planting date of July 10.

In 1989, Plant height, ear height, leaf area, days to mid-silk, and percentage of lodged plants were not significantly affected by increasing N rates from 70 to 130 kg/fa (Table 7). Although the proportion of lodged plants increased with increasing N rates, the differences were not significant. These results are in partial agreement with those obtained by Abdel-Gawad *et al.* (1974), and Lucas (1986).

Both stem diameter and active leaves number were significantly increased with increasing N rates. Similar results were also reported by Abdel-Gawad (1986), and Mohamed (1986). The percentage of barren plants decreased at the two higher N rates. Shafshak *et al.* (1981), and Younis (1985) found similar results in this concern. These results support the well-known observation that high N rates increase or promote vegetative growth parameters such as plant and ear heights and more ears, which in turn may lead to increased lodging.

Effect of N rates on yield, yield components, and grain N uptake

Grain yield was significantly increased between the 70 to 100 kg N/fa rates by 400 kg/fa, but not significant from 100 to 130 kg N/fa rates (Table 8). The increased grain yield might be due to the accumulated previous increases in ears number per plant, ear kernels number and kernel weight. Similar results were observed in both grain N content and grain N uptake. As grain N uptake is a function of grain N content and grain yield, it was expected that N uptake would also be higher at the higher N rates. These findings are in accordance with those reported by Kandil *et al.* (1984), and Younis (1985).

Stover yield was not significantly influenced by increasing N rates, however; there was a slight increase in stover yield between 70 and either 100 or 130 kg N/fa rates.

Despite there being non-significant differences in yield components in 1989, there is a clear trend for enhancing the ear parameters and reducing the population per unit area by increasing N rates from 70 to 130 kg/fa. The reduction in population might be due to the increased loss of damaged (lodged or broken) plants resulting from increasing N levels.

Table 7. Growth characters of corn as influenced by N fertilizer levels in the 1989 growing season.

N Rate (kg/fa)	Plant ht cm	Ear ht cm	Stem diam. mm	Active leaves no.	Leaf area cm^2	Days to mid-silk. no.	Barren plants %	Lodged plants %
70	249	104	16 a *	9.6 a	633	67.4	9.6 a	9.2
100	252	109	17 b	10.6 ab	612	65.7	7 b	11.4
130	255	114	17 b	11.6 b	633	66	6.3 b	15.1
	NS	NS			NS	NS		NS

* Means for each parameter followed by the same letter are not significantly different at the 0.05 level.
NS = not significant at the 0.05 level.

Table 8. Yield, yield components and grain quality as influenced by N fertilizer levels in the 1989 growing season.

N rate (kg / fa)	Populat-ion / fa no.	Ears / plant no.	Kernels / ear no.	Wt ear kernels g	Wt 100 kernels g	Grain yield kg/fa	Grain N %	Grain N uptake kg/fa	Stover yield kg/fa
70	20,000	0.93	466	145	32.4	2,200 a *	1.51 a	33.1 a	2,800
100	19,400	0.97	503	160.8	33.5	2,600 b	1.71 b	34.7 b	3,000
130	18,800	1.00	509	171.2	34	2,500 b	1.81 b	45.4 b	3,000
	NS	NS	NS	NS	NS				NS

* Means for each parameter followed by the same letter are not significantly different at the 0.05 level.
.NS = not significant at the 0.05 level.

The data indicate that corn plants under these experiment conditions were unable to benefit from N in excess of 100 kg/fa and this may be due to a plateau imposed by the genotype cv. Giza-2.

Nitrogen rate by PGR interaction effects

The N rate by PGR interaction effects on corn plant height and leaf area in the 1988 experiment are shown in table (9). Cycocel at 1200 ppm significantly decreased plant height relative to the control and 600 ppm CCC treatment at the 70 kg/fa N rate. At 100 kg N/fa, 150 ppm of GA_3 significantly decreased plant height by 16 cm compared to both CCC treatments. There were no significant differences between the effects of the control and any of the PGR treatments with 100 or 130 kg N/fa on plant height. It is evident from these results that the increased N rate diluted the deleterious effect of the CCC at the higher rate of 1200 ppm. This was probably because of the well-known physiological functions of N in promoting crop growth characteristics.

At the 100 kg N/fa rate, leaf areas at both CCC rates were greater than that of the control. The leaf area of CCC at 600 ppm was only higher than that of the 300 ppm GA_3 treatment. There were no significant differences recorded on the leaf area among any of the PGR treatments with the lower or the higher N rates.

Table 9. The interaction between N levels and plant growth regulators on corn plant height and leaf area (LA) in the 1988 experiment.

N rate	PGRs (ppm)				
(kg/fa)	Check (0)	GA_3 (150)	GA_3 (300)	CCC (600)	CCC (1200)
			Plant ht. (cm)		
70	253 ab*	251 a-c	250 a-d	258 a	240 cd
100	252 a-c	240 cd	248 a-d	256 a	256 a
130	250 a-d	246 a-d	238 d	242 b-d	254 ab
			LA (cm^2)		
70	634 a-c	634 a-c	590 c	617 a-c	631 a-c
100	599 c	632 a-c	608 bc	667 a	658 ab
130	612 bc	612 bc	637 a-c	602 c	608 bc

* Means for each parameter followed by the same letter are not significantly different at the 0.05 level.

II. Ethephon and Primo PGRs Experiment

Effect of PGRs on Vegetative growth parameters

All measured parameters were significantly affected by the PGR 13-combination treatments (Table 10). Application of both ethephon at either rates of 450 or 750 g/ha, and Primo at 800 g/ha at V6 growth stage significantly shortened plant height at 2-wk after the treatment as compared to the control. However, no significant differences were apparent on plant height among these three treatments (Table 10). Results also showed that plant height measured 2-wk after V6 stage was not affected by the application of PGRs at V10 stage. This last result was expected since V10 growth stage was not developed yet, consequently, PGRs of V10 were not applied at that sampling time.

Primo PGR applied at V6 stage at both 800 and 1200 g/ha significantly reduced plant height measured 2-wk after V10 stage. However, plant height measured at harvest was significantly suppressed by the highest rate of either PGRs applied at V6 stage. All other treatments applied at V6 did not affect plant height measured at the last three sampling dates. Yet, all treatments applied at V10 significantly reduced plant height measured 2-wk after the treatment, at silking, or at harvest (Table 10, Fig. 1 a-d). The highest rate of ethephon treatment resulted in the shortest plants measured at the same three sampling dates.

Ear height was also affected by the PGR treatments, especially those applied at V10 stage. The highest rate of ethephon applied at either V6 or V10 resulted in lowering position of the topmost ear (Table 10, Fig. 1 a-d).

Table 10. Vegetative growth parameters of corn as influenced by timing and application rates of PGRs ethephon (ETH) and Primo (CGA) in the 1992 field experiment.

Treatment no.	Time	PGR-rate (g a.i./ha)	Plant ht I➊ cm	Plant ht II➋ cm	Plant ht (silk) cm	Plant ht (harvest) cm	Ear ht (harvest) cm	Ear shank length cm	Silked plants no./170	Active leaves no.	Plant leaf area cm^2	Leaf area index	Plant moisture (at silk.) %
0		check - 0	96 ab *	262 a	332 a	330 a	151 a	15.4 b	45 a	13.4 ab	6668 a-c	5.1 a-e	81 b
1	V6	ETH- 150	84 a-d	252 a-c	320 a	323 ab	140 a-c	14.2 bc	43 ab	13.5 ab	6486 b-d	4.8 c-e	81 b
2	"	ETH- 450	80 cd	248 a-c	323 a	320 a-c	141 a-c	14.6 bc	44 ab	13.2 ab	6276 cd	4.7 de	81 b
3	"	ETH- 750	77 d	246 a-c	326 a	309 bc	126 de	15.8 b	42 ab	13.7 ab	6092 d	4.5 e	82 ab
4	"	CGA- 400	89 a-d	259 ab	326 a	320 a-c	146 ab	14.4 bc	44 ab	13.6 ab	7154 a	5.3 ab	81 b
5	"	CGA- 800	80 cd	234 c	312 ab	316 a-c	147 ab	12.7 cd	43 ab	14.0 a	6930 ab	5.2 a-c	81 b
6	"	CGA-1200	82 b-d	236 bc	310 ab	306 cd	136 b-d	13.5 b-d	43 ab	13.7 ab	7050 ab	5.3 a-c	82 ab
7	V10	ETH- 150	94 a-c	205 d	293 bc	280 e	118 ef	15.3 b	42 ab	13.2 ab	6761 a-c	5 a-d	83 ab
8	"	ETH- 450	99 a	196 d	246 e	242 g	110 f	19.1 a	42 ab	12.7 b	6518 b-d	4.9 b-e	83 ab
9	"	ETH- 750	98 a	186 d	231 e	236 g	107 f	18.5 a	43 ab	13.3 ab	6787 a-c	5 a-d	82 ab
10	"	CGA- 400	96 ab	232 c	278 cd	294 d	133 cd	14.6 bc	40 ab	13.9 a	7210 a	5.4 a	82 ab
11	"	CGA- 800	91 a-d	202 d	270 d	256 f	127 de	12.6 cd	32 c	13.5 ab	7049 ab	5.3 a-c	83 ab
12	"	CGA-1200	94 a-c	194 d	240 e	248 fg	126 de	11.6 d	39 b	13.6 ab	7001 ab	5.2 a-c	84 a

* Means for each parameter followed by the same letter are not significantly different at the 0.05 level.
➊Measured 2-wk after V6 growth stage. ➋Measured 2-wk after V10 growth stage.

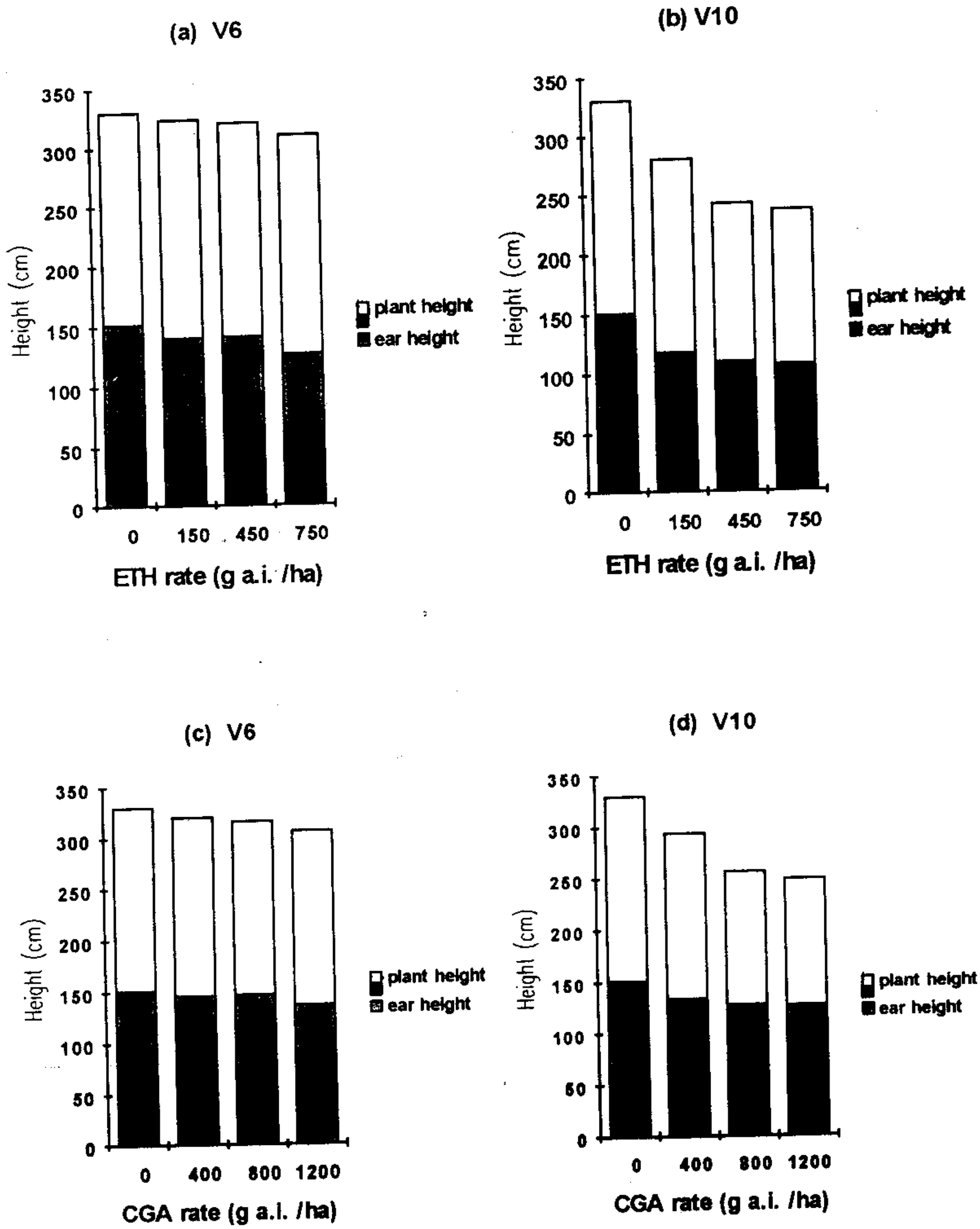


Fig. 1. (a-d) Response of plant height (at harvest) and ear height to application times and rates of ethephon (ETH) and Primo (CGA) PGRs as compared to the control.

This result indicates the action of ethephon as ethylene-releasing compound on reduction of basal internode elongation. It was also observed that the lowest rate of each PGR applied at V6 did not significantly change all measured plant heights or ear height when compared with the control. In general, the second application time of PGRs was more effective in reducing plant, and ear heights than the first time. This result is mainly due to more leaves and nodes were developed at V10 stage producing greater plant leaf area to receive more amount of PGRs, and giving more sites for PGRs to act upon.

Similar results for ethephon were obtained by Gaska and Oplinger (1988a). They observed that plant, and ear heights were decreased to 20 % with the rate of 560 g/ha of ethephon. Also, the present results are in agreement with those reported by Sagaral and Parrish (1989). They found that the reduction in corn plant height tended to increase with increasing rate of ethephon from 280 to 560 g/ha when applied at 5-6 leaf stage. They also added that ethephon was characterized as an anti-lodging agent in field corn, and sweet corn.

The length of ear shank was significantly increased with ethephon applied at either 450 or 750 g/ha at V10 stage. Meanwhile, it was shorter with both 800 and 1200 g/ha applied at the same time and only with the middle rate of Primo applied at the V6 stage (Table 10). The longer ear shank might be a yield disadvantage because ears might become more susceptible to breakage and rodents attack in the field.

Except for the two higher rates of Primo applied at V10 stage, the number of silked plants was not significantly affected by PGR treatments applied at both stages. Applying Primo PGR at either 800 or 1200 g/ha at V10 stage significantly decreased the number of silked plants than the control by 29 and 13 %, respectively (Table 10). Concerning the effects of Primo on plant height and flowering, the present findings are in accordance with those noticed by Kern (1993). He reported that later application (11-12 leaf stage) of higher rate (1500 g/ha) of Primo PGR had the highest effect on reducing height and delaying the flowering of plants. These results suggest that using of Primo PGR would be of value for corn breeders to control flowering.

The PGR-treated plants at either stage did not significantly differ from those of the control in the number of functional leaves. However, averaged over application timing and rates, more active leaves (13.7) per plant resulted from using Primo compared with 13.3 from using ethephon (Table 10). Plant leaf area (PLA) was not significantly changed with PGR treatments, except with the highest rate of ethephon applied at the V6 leaf stage. This last treatment reduced PLA by 8.6 % in comparison with the control. Meanwhile, there were 7 and 8 % non-significant increases in PLA resulted from 400 g/ha of Primo applied either at V6 or V10 stage, respectively (Table 10, Fig. 2 a,b). Leaf area index (LAI) exhibited similar trend to its relative PLA as affected by PGR treatments. Data of PLA and LAI show that Primo PGR increased both values whereas ethephon decreased them in comparison with the check.

Plant moisture content at silking was significantly increased by the highest rate of Primo applied at later V10 stage (Table 10). This result may be due to the action of Primo PGR on closing the stomata. As a result, stomatal resistance would increase and transpiration would decrease so plants would become succulent. Shanahan and Nielsen (1987) reported that anti-gibberellin PGRs could increase corn plants tolerance to water stress conditions.

Qualitative observations

It was observed that the higher rates of ethephon (450 or 750 g/ha) applied at V10 stage increased the brace root formation in corn plants. Brace root development was expressed as number of active nodes, number of roots per node, and the length of brace root. Similar observation was reported by Fritz (1989) and Cliquet *et al.* (1991). It was also noticed that the Primo-treated plants with 800 or 1200 g/ha applied at either growth stage had a dark-green leaves.

Effect of PGRs on corn yields, assimilate partitioning, and lodging

Grain yield was significantly influenced by the PGR treatments (Table 11, Fig. 3 a,b). Results showed that there was a 7 % increase in grain yield resulting from the lowest rate of Primo (400 g/ha) applied at six-leaf stage. However, a reduction in grain yield was observed with most other used PGR treatments. The highest reduction (17 %) in grain yield was recorded for the highest rate (1200 g/ha) of Primo applied at V10 stage.

Stover, and total yields of PGR-treated plots did not significantly differ from those of the control (Table 11). The smallest dose of Primo (400 g/ha) applied at V6 resulted in a 10 and 8 % increase in stover, and total yields, respectively. Meanwhile, the highest level of ethephon (750 g/ha) applied at

Table 11. Corn yields, selected ear parameters, assimilate partitioning, and lodging as influenced by timing and application rates of PGRs ethphon (ETH) and Primo (CGA) in the 1992 field experiment.

Treatment no.	Time	PGR-rate (g a.i./ha)	Grain yield (15.5% moisture) Mg/ha	Grain yield %	Stover dry yield Mg/ha	Total dry yield Mg/ha	Harvest index %	Lodged plants %	Ear H_2O %	Shelling %	100 Kernel wt g	Total shoot dry wt g	Proportion of total shoot dry wt: grain %	leaves %	stem %	ear non-grain %
0		check - 0	9.06 ab*	100	9.99 ab	17.66 ab	44 ab	7.6 a	50 ab	85 a	30.1 ab	295 a	46 a	16 f	23 b-d	15 bc
1	V6	ETH- 150	8.52 b-d	94	9.80 ab	17 ab	43 ab	5.3 b	52 ab	84 a-c	29.5 ab	265 a-c	43 ab	17 c-f	25 a-c	15 bc
2	"	ETH- 450	8.18 c-e	90	9.71 ab	16.62 b	42 a-c	2.9 b-d	53 a	84 a-c	29.1 ab	240 cd	43 ab	17 ef	25 ab	15 bc
3	"	ETH- 750	8.8 de	97	9.32 ab	16.14 b	42 a-c	2.4 cd	53 a	85 ab	28.4 ab	224 d	43 ab	17 c-f	26 a	14 c
4	"	CGA- 400	9.69 a	107	10.94 a	19.13 a	43 ab	2.9 b-d	50 ab	85 a	30 ab	285 ab	46 a	17 d-f	23 b-d	15 bc
5	"	CGA- 800	8.86 a-d	98	9.70 ab	17.19 ab	44 ab	3.5 b-d	51 ab	84 a-c	29.4 ab	260 a-d	45 ab	17 c-f	23 a-d	15 bc
6	"	CGA-1200	8.47 b-d	93	10.28 ab	17.42 ab	41 a-c	4.1 bc	51 ab	84 a-c	28.7 ab	252 b-d	43 ab	18 b-e	25 ab	15 bc
7	V10	ETH- 150	9 a-c	99	9.03 ab	16.63 b	46 a	2.4 cd	49 b	84 a-c	29.1 ab	231 cd	46 ab	17 c-f	21 d	16 a-c
8	"	ETH- 450	8.20 c-e	91	9.51 ab	16.44 b	43 ab	1.8 cd	50 ab	83 bc	31 a	249 b-d	44 ab	17 c-f	23 a-d	16 ab
9	"	ETH- 750	8.18 c-e	90	8.82 b	15.73 b	44 ab	1.2 d	49 b	83 c	31 a	256 b-d	42 b	19 bc	23 b-d	17 a
10	"	CGA- 400	9.18 ab	101	9.76 ab	17.52 ab	44 ab	2.9 b-d	50 ab	84 a-c	27.9 ab	266 a-c	44 ab	18 b-d	23 b-d	15 bc
11	"	CGA- 800	8.19 c-e	90	10.38 ab	17.29 ab	40 bc	1.8 cd	52 ab	85 a	27.2 b	249 b-d	44 ab	20 ab	21 d	16 ab
12	"	CGA-1200	7.52 e	83	10.46 ab	16.81 b	38 c	1.2 d	52 ab	84 a-c	23.7 c	243 cd	42 b	20 a	22 cd	16 ab

* Means for each parameter followed by the same letter are not significantly different at the 0.05 level.

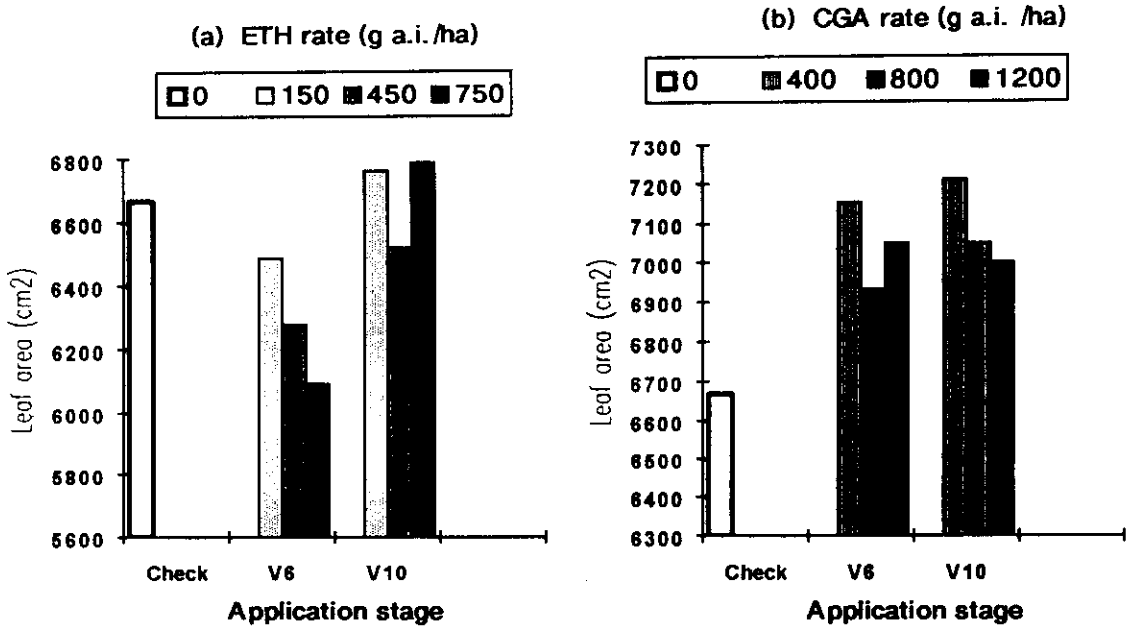


Fig. 2. (a, b) Plant leaf area as affected by ethephon (ETH), and Primo (CGA) timing and rate of application as compared to the control.

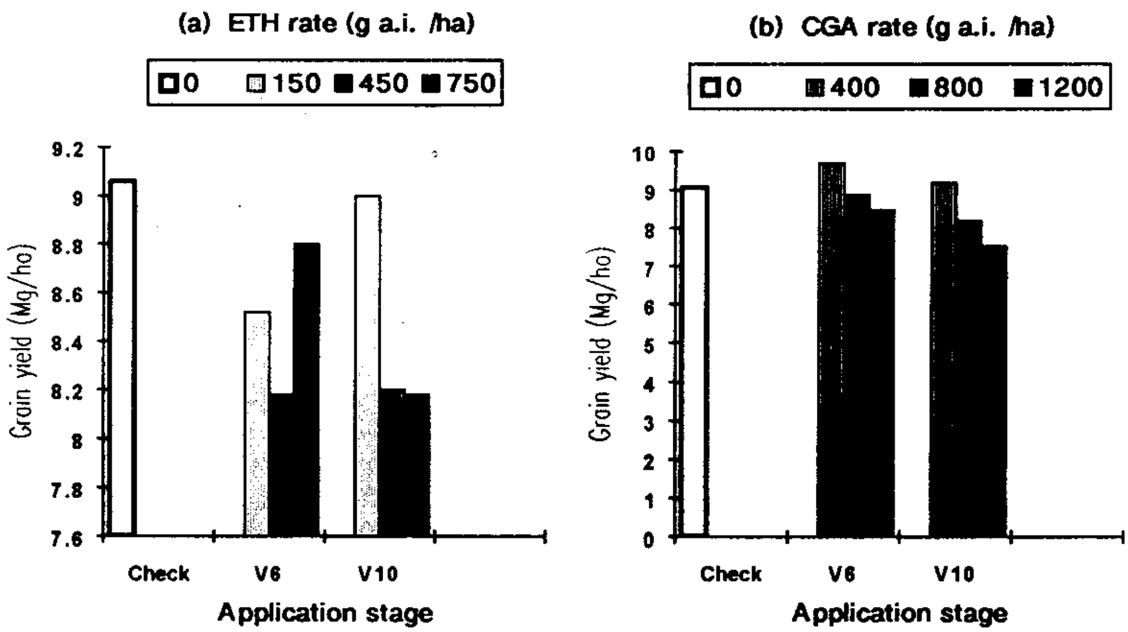


Fig. 3. (a, b) Grain yield as affected by ethephon (ETH), and Primo (CGA) timing and rate of application as compared to the control.

ten-leaf stage resulted in 12 and 11 % reduction in the same two parameters, respectively.

These increases or reductions in grain, stover, and total yields might be due to the associated changes, previously mentioned, in plant height, number of active leaves, and/or plant leaf area. Yield data of this experiment are in agreement with those obtained by Gaska and Oplinger (1988a and b), Sagaral and Parrish (1989), and Kern (1993). In addition to the results obtained by Cliquet *et al.* (1991) who reported that ethephon decreased grain yield correlatively with an enhancement of the size of brace roots.

Harvest index- was called migration coefficient- characterizes the movement of dry matter to the harvestable parts of the plant (grain yield in corn case). It is defined as follows: *Harvest index = economic yield / biological yield (excluding the roots) x 100*. Harvest index was significantly decreased with the highest rate of Primo applied at V10 stage (Table 11, Fig. 4 a,b). This result would be expected since grain yield was reduced by 17 % and the total yield was decreased only by 5 % for the same treatment.

Ear moisture content of PGR-treated plants did not significantly differ from that of non-treated ones, while it was higher with ethephon applied at V6 stage than that applied at V10 stage (Table 11). The higher rates of ethephon (450 or 750 g/ha) applied at V10 stage significantly reduced shelling percentage. All other PGR treatments did not significantly affect this character in comparison with the control (Table 11). The last result is mainly due to the deleterious effect of ethephon applied at high rates and late stage on number of kernels since the weight of 100 kernels was not significantly changed with these treatments. This result could also be due to the increase obtained in the ear non-grain proportion specially with 750 g/ha of ethephon applied at V10 stage. Gaska and Oplinger (1988a) reported similar observation for the effect of ethephon on number of kernels.

Weight of 100-kernel was significantly affected by PGR applications. When averaged over timing and rates, Primo was more stressful than ethephon in this aspect. The highest rate of Primo applied at V10 stage, significantly decreased 100-kernel weight by 21 % below the control (Table 11). This last result might be due to delaying the development of reproductive organs which in turn limits the kernel-filling period and subsequently decreases kernel growth and finally may reduce grain yield.

Percent of lodged plants was significantly decreased with all PGR applications (Table 11, Fig. 5 a , b). The highest rates of both ethephon (750 g/ha) and Primo (1200 g/ha) applied at V10 stage resulted in the lowest percentage of lodged plants. It was also observed that the V10-application time was more effective than V6 in reducing stalk lodging as averaged over PGRs and their rates. The reduction in plant, and ear heights, enhancing brace root development, or/and increasing stalk stiffness might be the reasons for minimizing corn lodging at V10 vs. V6 as averaged over PGRs and their rates.

The PGR-treated plants exhibited a significant effect on total dry weight of shoot and its partitioning to the plant organs at harvest (Table 11). Except for the 150 g/ha ethephon rate, and the 400 or 800 g/ha Primo rates applied at V6 stage, the other PGR treatments significantly reduced the total

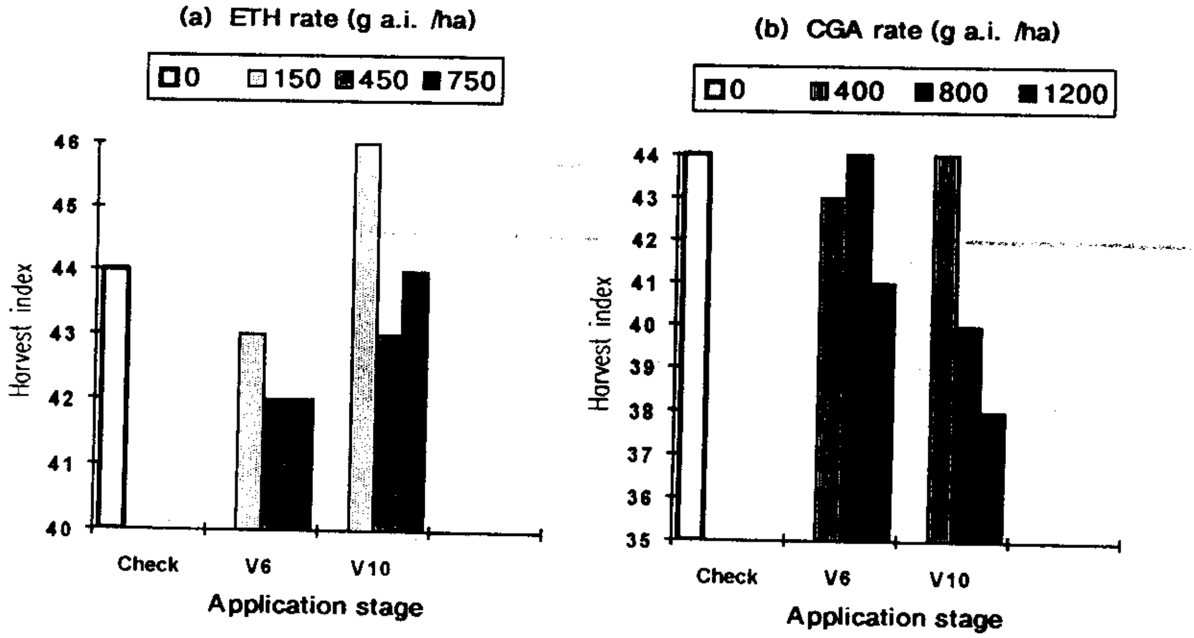


Fig. 4. (a, b) Harvest index as affected by ethephon (ETH), and Primo (CGA) timing and rate of application as compared to the control.

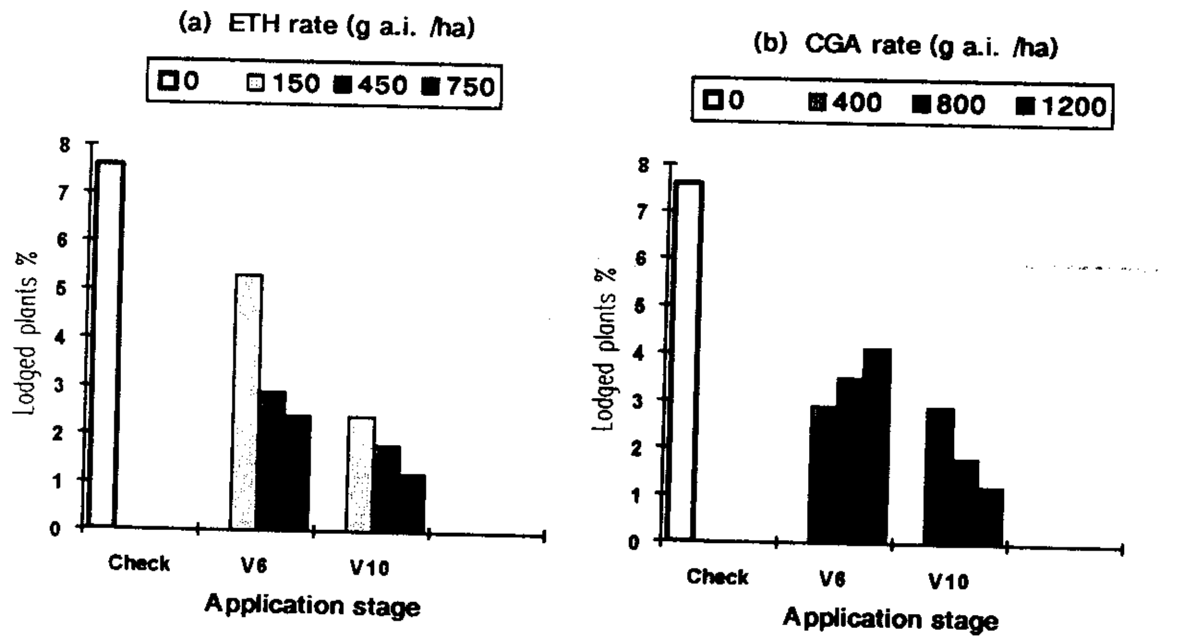


Fig. 5. (a, b) Lodged plants percent as affected by ethephon (ETH), and Primo (CGA) timing and rate of application as compared to the control.

shoot dry weight. Also, it was noticed that total dry weight of ethephon-treated plants (244.2 g) was less than that of Primo's (259.2 g) when averaged over timing and rates. This result means that ethephon retarded shoot growth more than Primo did, and is almost in agreement with the previous result obtained for the grain yield.

Grain proportion was significantly decreased with the highest rate of both ethephon and Primo applied at V10 stage, yet other PGR combinations had no significant effect on grain percentage (Table 11, Fig. 6 a-b). Except for 1200 g/ha Primo rate, leaf percentage was not significantly altered by the application of PGRs at V6 stage. However, the three rates of Primo and the highest rate of ethephon applied at V10 stage significantly increased leaves proportion as compared to the control. The highest ethephon rate of 750 g/ha applied at six-leaf stage significantly increased stem percentage. Meanwhile, other PGR treatments did not significantly change this proportion as compared to the control.

Results in table (11) also showed a significant increase in the ear non-grain components due to the application of 750 g/ha ethephon at V10 stage. This result is almost in agreement with that of the previously mentioned on shelling percentage. It was also observed that the effect of this treatment on shelling percentage, leaves, and ear non-grain proportions were in contrast with those recorded for both grain yield and grain proportion.

The results of distribution of shoot dry matter might help in interpretation of PGR effects on grain yield. For example, the reduction in grain yield associated with the highest rates of both PGRs applied at V10

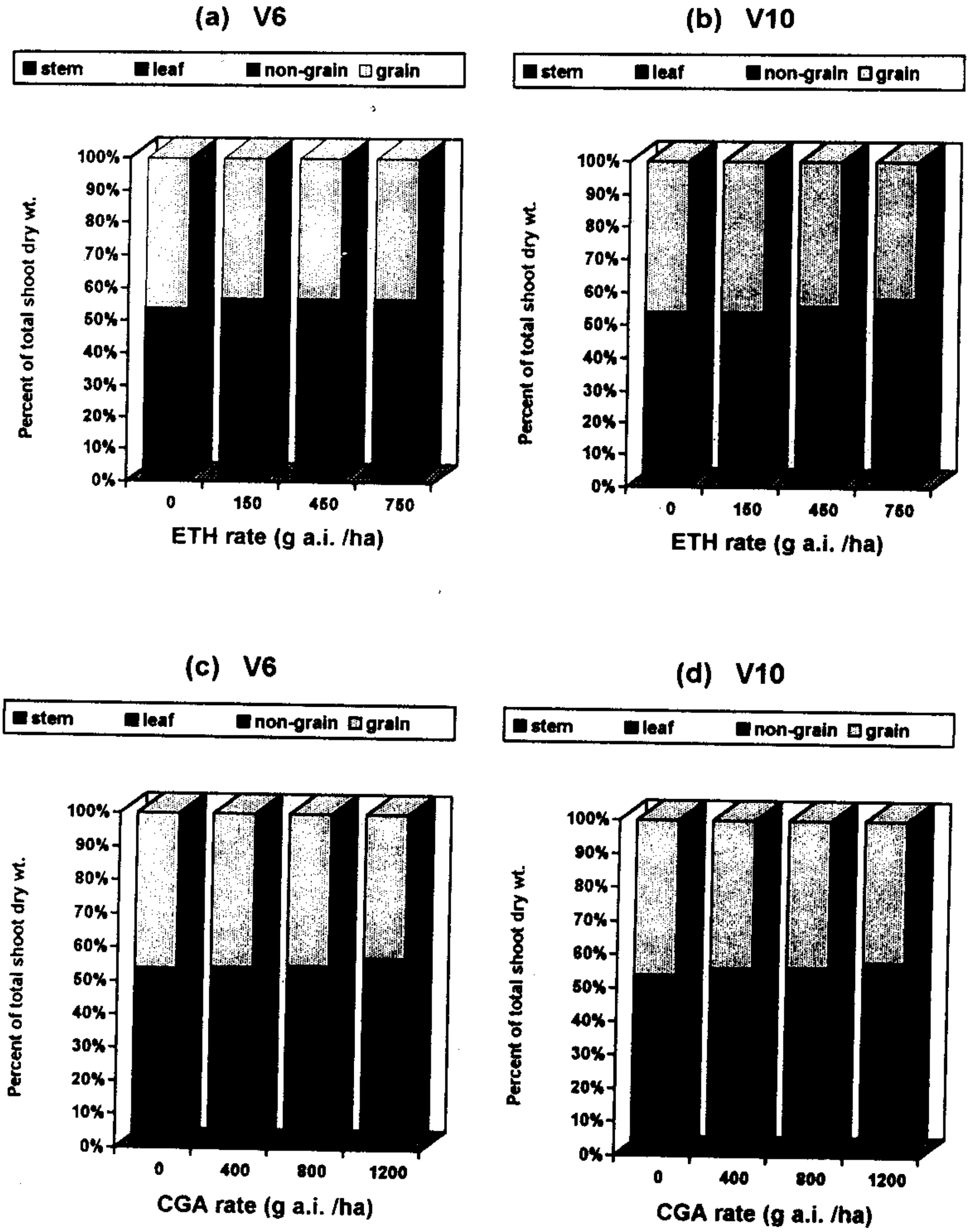


Fig. 6. (a-d) Response of assimilate partitioning to application times and rates of ethephon (ETH) and Primo (CGA) PGRs as compared to the control.

stage might be due to the reduction in total shoot weight or/and due to the increase in the shoot non-grain portions.

Crop quality measurements

Many recent studies have shown that ethephon or other anti-lodging agents can modify corn plant growth characteristics. Consequently, corn yields could be altered by the application of such PGRs, however, there is fewer published information concerning their effects on corn quality.

Data in table (12) indicated that stover N content determined at silking and at harvest was significantly affected by PGR applications. The highest ethephon rate (750 g/ha) applied at V10 stage significantly increased stover N percentage measured at silking by 14% over the control. However, stover N content estimated at harvest was significantly increased with the middle rate of Primo applied at V6 stage, both middle and highest rates of ethephon and Primo applied at V10 stage as compared to the control. There were no significant differences observed among the means of these five treatments in this aspect. It was also noticed that changing the rate of application within each PGR had no significant difference on stover N content. This was true with that determined at silking, but there was an exception for the middle rate of Primo applied at V6 stage with that checked at harvest.

Although there were no significant differences detected on the other determined parameters (Table 12) as a function of PGR treatments, the values of these parameters were higher with PGRs applied at V10 stage than those applied at V6 stage. Also, it was observed that N uptake values averaged over timing and rates of application were higher with Primo PGR than with

Table 12. Grain, stover, and total N uptake and grain N, stover N, and stover NO3-N concentrations as affected by timing and application rates of PGRs ethephon (ETH) and Primo (CGA) in the 1992 field experiment.

Treatment no.	Time	PGR-rate (g a.i./ha)	Grain N (harvest) %	Stover N (silk.) %	Stover N (harvest) %	Stover-NO3-N (silk) g/kg	N uptake grain kg/ha	N uptake stover kg/ha	N uptake total[ς] kg/ha
0		check - 0	1.40	1.73 b-e*	1.02 e	2.97	108	102	220
1	V6	ETH- 150	1.38	1.61 e	1.05 de	2.33	99	102	211
2	"	ETH- 450	1.40	1.70 c-e	1.12 b-e	3.36	97	109	216
3	"	ETH- 750	1.48	1.78 b-e	1.11 b-e	3.18	101	103	215
4	"	CGA- 400	1.39	1.68 d-e	1.05 c-e	2.92	114	115	241
5	"	CGA- 800	1.40	1.67 d-e	1.25 a	2.54	105	121	237
6	"	CGA-1200	1.40	1.72 c-e	1.12 b-e	2.90	100	115	226
7	V10	ETH- 150	1.42	1.82 a-d	1.12 b-e	2.69	108	101	220
8	"	ETH- 450	1.51	1.90 ab	1.19 ab	3.29	105	112	228
9	"	ETH- 750	1.46	1.97 a	1.16 a-d	3.21	101	102	213
10	"	CGA- 400	1.45	1.76 b-e	1.12 b-e	2.49	112	109	233
11	"	CGA- 800	1.45	1.74 b-e	1.18 a-c	2.62	100	122	233
12	"	CGA-1200	1.55	1.86 a-c	1.17 a-d	3.29	98	123	232
			NS			NS	NS	NS	NS

[ς] Total N uptake was calculated by multiplying the grain plus stover N contents by 1.05.
* Means in each column followed by the same letter are not significantly different at the 0.05 level.
NS= not significant at the 0.05 level.

ethephon. This last result is similar to those noticed previously on the corresponding grain, stover and total yields.

Data in table (12) also showed that concentrations of total N and NO_3-N were inversely related to grain, and stover yields. It seems from this observation. that the PGR-treated plants were continuing nitrate uptake even in the case of growth retarding. Levels of NO_3-N in plant shoot at silking were slightly (not significantly) affected by the used PGR treatments. It was noticed that the stover NO_3-N was increased over that of the control by applying the highest and the middle ethephon rates at either V6 or V10 stage, and with the highest level of Primo applied at V10 stage. These results are similar to those reported by Fales and Wilkinson (1984) on pearl millet (*Pennisetum americanum* L. Leeke) treated with mefluidide PGR.

Interaction effects

Summary of ANOVA results for all measured parameters including the main effects of PGRs (ethephon vs. Primo), application stage (V6 vs. V10), and rates nested within each PGR as well as their interactions are shown in table (13).

Application time by PGR interaction

The effects of the interaction of ethephon (ETH) and Primo (CGA) with stage of application on the characters that indicating significant interaction sum of squares are shown in Fig.(7 a - j).

For plant height measured at both sampling dates, i.e., (2-wk after V10 and at harvest); it is apparent that the interaction was in the magnitude and

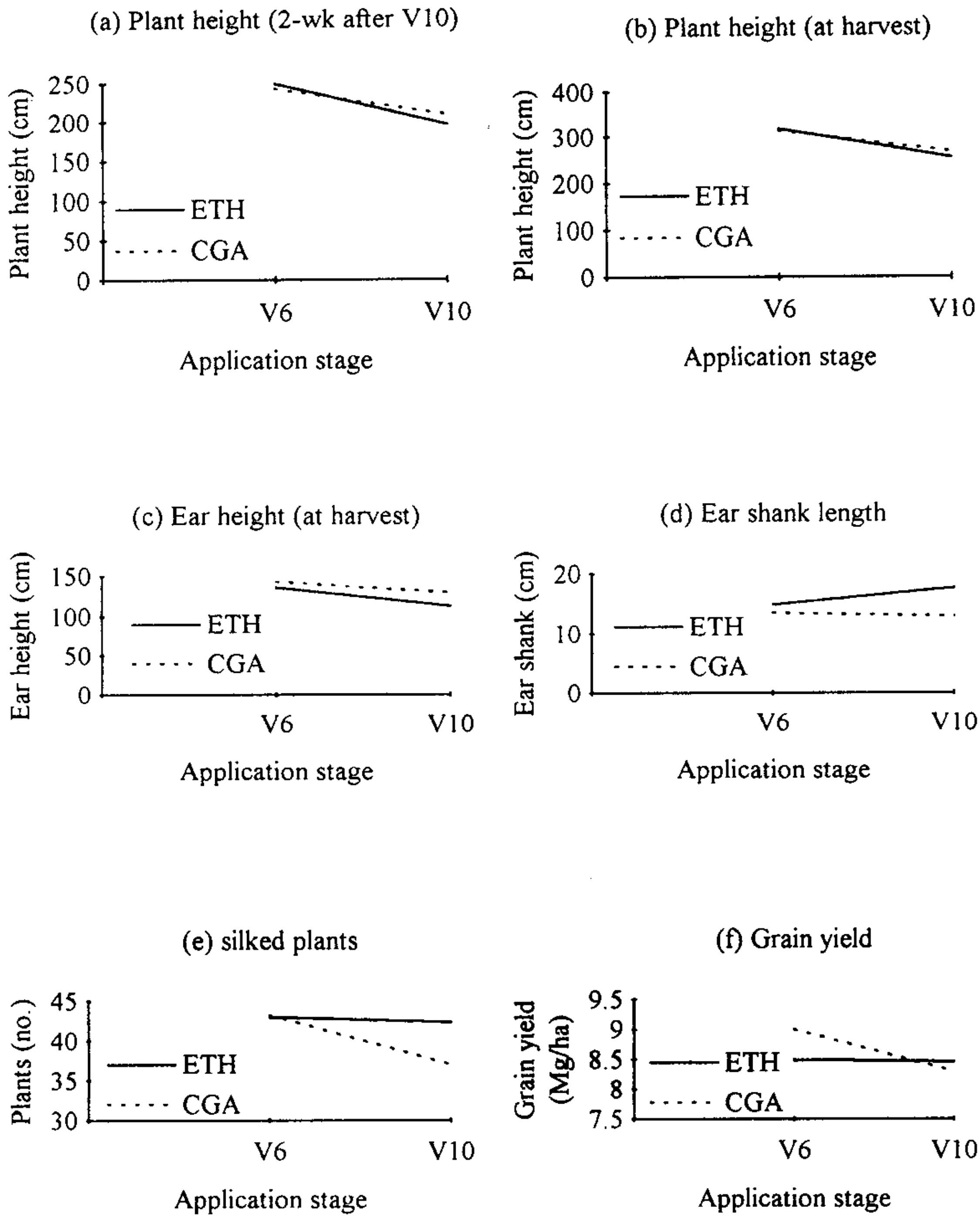
Table 13. Significance of main effects of ethephon (ETH) and Primo (CGA) PGR-combinations, and their interactions in the ANOVA analyses for all measured corn parameters in the ETH and CGA experiment done in Pennsylvania, USA, in 1992.

Measured Parameter	All 13-combina-tion. treat.	Time V6 vs. V10	PGR ETH. vs. CGA.	Time x PGR	Rate (PGR)	Time x Rate (PGR)
Plant ht. (2-wk after V 6)	**	**	NS	NS	NS	NS
Plant ht. (2-wk after V10)	**	**	NS	*	**	NS
Plant ht. (at silk.)	**	**	NS	NS	**	**
Plant ht. (at harvest)	**	**	NS	**	**	**
Ear ht. (at harvest).	**	**	**	*	**	*
Stem diam(3rd internode)(at silk)	NS	NS	NS	NS	NS	NS
Ear shank length	**	*	**	**	**	NS
Silked plants no.	**	**	*	**	NS	NS
Active leaf no. (at silk.)	NS	NS	*	NS	NS	NS
Plant leaf area (at silk.)	**	*	**	NS	NS	NS
Leaf area index (at silk.)	**	*	**	NS	NS	NS
Shoot H_2O content (at silk.)	*	**	NS	NS	NS	NS
Grain yield (15.5 % H_2O)	**	NS	NS	**	**	NS
Stover dry yield	NS	NS	*	NS	NS	NS
Total dry yield	NS	NS	**	NS	NS	NS
Harvest index	*	NS	NS	*	NS	NS
Lodged plants %	**	**	NS	NS	NS	NS
Ear H_2O content	*	*	NS	**	NS	NS
Shelling %	NS	NS	NS	NS	NS	NS
100-kernel wt.	**	NS	**	**	NS	NS
Total shoot dry wt.(TSDW)	*	NS	*	NS	NS	NS
Grain wt % of TSDW	NS	NS	NS	NS	NS	NS
Leaves wt % of TSDW	**	**	**	*	*	NS
Stem wt % of TSDW	**	**	*	NS	NS	NS
Ear non-grain wt%of TSWA	**	**	NS	NS	NS	NS
Grain N % (at harvest)	NS	**	NS	NS	NS	NS
Stover N % (at silk.)	**	**	NS	NS	*	NS
Stover NO_3-N conc.(at silk.)	NS	NS	NS	NS	NS	NS
Stover N % (at harvest)	**	NS	NS	NS	*	NS
Grain N uptake (harvest)	NS	NS	NS	NS	*	NS
Stover N uptake (harvest)	NS	NS	**	NS	NS	NS
Total N uptake♣(harvest)	NS	NS	**	NS	NS	NS

*,** significant at the 0.05 and 0.01 probability levels, respectively.
NS not significant at the 0.05 level.
♣ Calculated by multiplying the grain plus stover N contents by 1.05

direction of the response. That is the response was greater for ETH at V6 than for CGA and the reverse occurred at V10 where the response for CGA became greater than the response for ETH (Fig. 7 a,b). As for ear height; the interaction was also in magnitude showing that the response to CGA and ETH was greater at V6 than at V10 (Fig. 7 c). With regard to ear shank length (Fig. 7 d); it is apparent that the response to ETH was greater at V10 than at V6, while the response to CGA was nearly the same at both stages. Regarding to the number of silked plants; most of the interaction is apparently due to simple effect of CGA (Fig. 7 e). The effect of this material is toward decreasing the number of silked plants as application stage changed from V6 to V10.

In figure (7 f) for grain yield; the interaction is evidently in magnitude and direction. At V6, CGA enhanced the amount of grain yield, however; at V10, a reduction in grain yield occurred. As for ETH, a slight decrease in grain yield occurred in V10 in comparison to V6. Both harvest index (Fig. 7 g) and 100-kernel weight (Fig. 7 i) show the same pattern, where the response to both PGRs was greater at V10 than at V6, however in different direct. That is a high increase occurred in harvest index and 100-kernel weight with ETH and a sharp reduction in both parameters occurred with CGA. For ear moisture percentage; Fig. (7 h) shows a true response in different direction for both PGRs. At V6, ETH increased the percent of moisture followed by a reduction in V10. On the contrary, the percent of moisture was greater at V10 than at V6 with CGA. As for leaves weight percentage; a slight response to both PGRs could be witnessed (Fig. 7 j). This response was enhanced at V10 and this enhancement was clearer for CGA than for ETH.


(a) Plant height (2-wk after V10)
Plant height (cm)
250
200
150
100
50
0
ETH
CGA
V6
V10
Application stage
(b) Plant height (at harvest)
Plant height (cm)
400
300
200
100
0
ETH
CGA
V6
V10
Application stage
(c) Ear height (at harvest)
Ear height (cm)
150
100
50
0
ETH
CGA
V6
V10
Application stage
(d) Ear shank length
Ear shank (cm)
20
10
0
ETH
CGA
V6
V10
Application stage
(e) silked plants
Plants (no.)
45
40
35
30
ETH
CGA
V6
V10
Application stage
(f) Grain yield
Grain yield (Mg/ha)
9.5
9
8.5
8
7.5
ETH
CGA
V6
V10
Application stage

(continued)

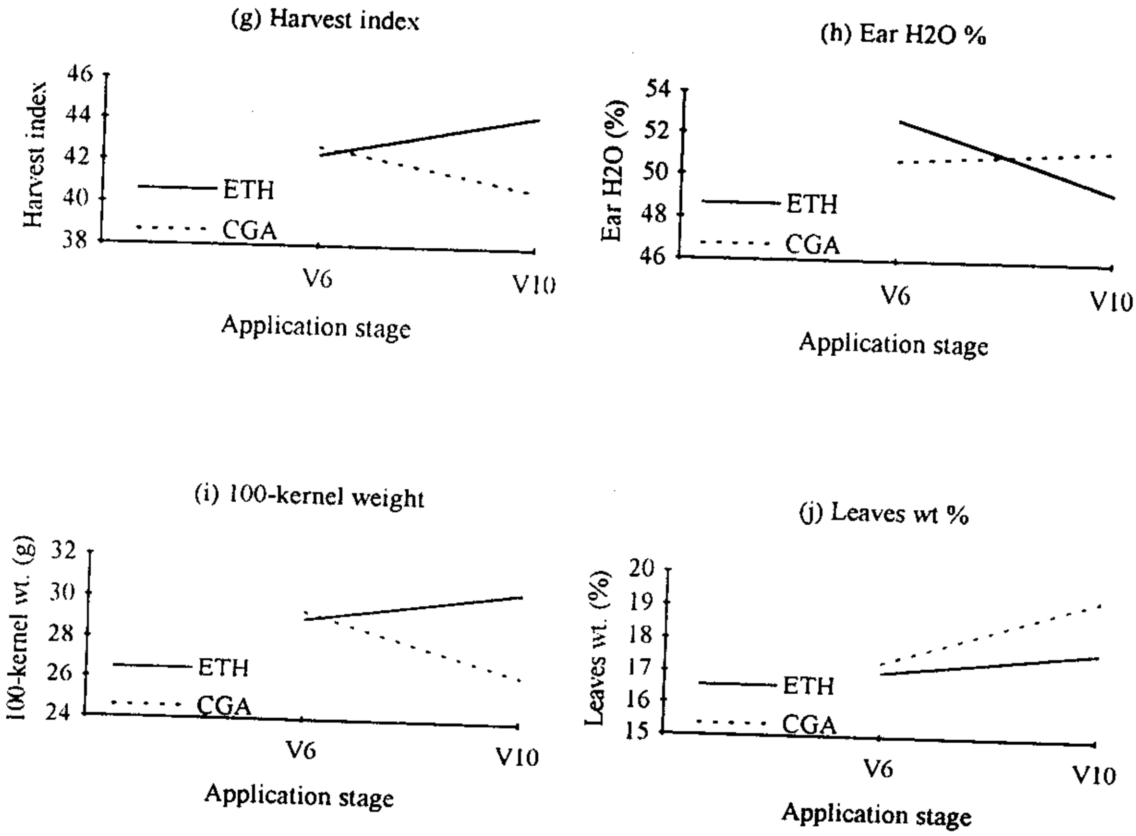


Fig. 7. (a- j) Type of application stage by PGR significant interaction effects on the measured corn parameters in 1992 experiment.

Rate (PGR), and time by rate (PGR) interactions

The rates used in this trial are considered to be nested within each PGR, i.e., the rates used for ethephon are quite different from those used for Primo (Table 10). Plant height, at both silk. and harvest, and ear height at harvest differed for rates within each PGR as well as for rates within each PGR by stage of application. Moreover, plant height two weeks after V10, grain yield, leaves weight percentage, stover N and NO_3-N % at silk., and stover N % at harvest are significantly different for various rates within each PGR (Table 13).

Conclusion

The used PGR treatments significantly modified vegetative growth characteristics of corn plants. They decreased plant height measured at different growth stages, lowered ear position, and so minimized stalk lodging. The middle and highest rates of ethephon (450 and 750 g/ha) increased the length of ear shank; however, it was decreased with those of Primo (800 and 1200 g/ha) when all were applied at V10 stage. The application of 800 or 1200 g/ha Primo rates applied at V10 stage delayed silking by 29 and 13%, respectively as compared to control. Treatments of 400 g/ha Primo applied at either V6 or V10 increased plant leaf area, and LAI, yet the two parameters were decreased with the highest rate of ethephon applied at V6 stage. The highest rate of Primo applied at V10 stage did increase plant moisture content at silking.

Grain yield and harvest index were significantly affected by PGR applications, however, stover, and total yields were not as compared to those of the control. The treatment of 400 g/ha Primo applied at V6 stage increased grain yield by 7% as compared to the control. Yet, there was a 17% reduction in grain yield resulting from the same PGR applied at V10 stage with the rate of 1200 g/ha. These results indicate that selecting both the right time and the proper rate of PGR application is very important for achievement of grain yield in addition to the desired growth modifications.

Shelling percentage was decreased by the application of ethephon at either 450 or 750 g/ha rate, however; the 1200 g/ha Primo decreased the 100-kernel weight when added at the same time of application

Ethephon and Primo could be characterized as plant growth retardants and this was evident with the total dry weight of shoot. The distribution of shoot dry matter among the plant organs might explain how such PGRs affect the grain yields. Also, results from this study indicate that the ethephon and Primo PGRs could be used as tools for corn quality enhancement. The V10 application time of ethephon and Primo was more effective in this concern than the V6 was. Concentrations of total N and NO_3-N were inversely related to dry matter accumulation. The used PGRs treatments did not increase stover NO_3-N levels when determined at silking. However, for safety, NO_3-N testing on such PGR-treated plants should be run before using to feed the ruminants on.

2. FERTILIZATION

I. NPK EXPERIMENT

Effect of N rate on vegetative growth parameters

Increasing N rate from zero to 60 kg/fa significantly increased plant height, ear height, stem diameter, number of active leaves, and leaf area in both seasons of study (Table 14). Similar results for these parameters can be found inclusively in those obtained by Younis (1985), and Salwau and Shams El-Din (1992). However, number of days to mid-silking and percentage of barren (earless) plants were significantly decreased due to the first increment of N rate (Table 14). The reduction in barren plants percentage with increasing N rate support the necessity of N for the development of reproductive organs of corn plants. The result of mid-silking is in agreement with those obtained by Awad (1979), and Abdel-Gawad *et al.* (1983). As for barren plants, Salem *et al.* (1982), and Nofal (1994) found the same.

Except for leaf area in 1988, all other measured parameters had a non-significant response to increasing N rates from 60 to 120 kg/fa (Table 14). The greatest leaf area was obtained from 60 kg/fa in 1988, however; the 90 kg treatment resulted in more active leaves per plant in 1989. In both years, the percentage of lodged plants was not significantly affected by the N rates. Similar result, regarding the effect of N rates on percent of lodged plants, was obtained by Abdel-Gawad *et al.* (1974).

Data in table (14) showed that most of the vegetative parameters responded only to the first increment of 60 kg N rate. Planting Giza-2 synthetic corn variety on such a fertile soil (with 0.14 % total N) might be the reason of this result.

Table 14. Vegetative growth parameters of corn as influenced by fertilizer N rate in the 1988 and 1989 growing seasons.

N Rate (kg/fa)	Plant ht cm	Ear ht cm	Stem diam. mm	Active leaves no.	Leaf area cm²	Days to mid-silk. no.	Barren plants %	Lodged plants %
					1988			
0	239 a *	103 a	17 a	8.7 a	556 a	62 a	21 a	17.7
60	253 b	114 b	19 b	9.7 b	643 c	59.6 b	10.8 b	17.2
90	247 b	108 ab	18 b	10 b	611 bc	60.3 ab	9.8 b	17.9
120	249 b	110 b	18 b	9.9 b	598 b	59.5 b	10 b	21.8
								NS
					1989			
0	229 a	91 a	15 a	8.2 a	509 a	69.7 a	20.6 a	10.9
60	260 b	113 b	17 b	9.9 b	646 b	67 b	7.1 b	8.4
90	252 b	107 b	17 b	10.8 c	658 b	66.9 b	6.8 b	8.7
120	258 b	109 b	17 b	10.5 bc	669 b	67.3 b	5.8 b	8.5
								NS

* Means for each parameter within year followed by the same letter are not significantly different at the 0.05 level.
NS = not significant at the 0.05 level.

Effect of N rate on yield, yield components, and grain N uptake

Grain yield was significantly increased in both years by increasing N rate from zero to 60 kg/fa (Table 15). However, the increases in grain yield were not significant as N rate increased from 60 to 120 kg N/fa. The 90 kg N/fa significantly increased grain yield by 47 and 67 % over the control in 1988 and 1989, respectively. Results of grain yield are in accordance with those reported by Abdel-Gawad *et al.* (1974), Amoruwa *et al.* (1987), and El-Hosary and Salwau (1989).

Similarly, most of ear and kernel characters were higher with 90 kg N/fa as compared to other N treatments (Table 15) and these increases might be the reason for enhancing grain yield with this N rate. Results of ear and kernel parameters are in a good agreement with the findings of Salem *et al.* (1982), and El-Hosary and Salwau (1989).

Increasing N rate up to 120 kg N/fa gradually increased grain N content (Table 15); however, the difference became significant only at the high N rates (120 kg in 1988, and 90 and 120 kg in 1989).

Since grain N uptake (removal) is obtained by multiplying the concentration of N in the grain by the grain yield, it was expected that N uptake would also increase at the higher N rates. Grain N removal was significantly increased with increasing N rate up to 60 kg in 1988 and up to 90 kg in 1989 (Table 15).

In 1989, stover yield responded to N rates similarly to grain yield in both years (Table 15).

Table 15. Yield, yield components and grain quality of corn as influenced by fertilizer N rate in the 1988 and 1989 growing seasons.

N Rate (kg/fa)	Populat-ion/fa no.	Ear/ plant no.	Kernel/ ear no.	Wt ear kernels g	Wt/100 kernel g	Grain yield kg/fa	Grain N %	Grain N uptake kg/fa	Stover yield kg/fa
				1988					
0	12,200	0.79 a *	410 a	112 a	30.3	1,500 a	1.39 a	21 a	---
60	12,700	0.90 ab	476 b	132 b	30.7	2,100 b	1.46 a	30.3 b	---
90	13,300	0.94 b	481 b	139 b	32.1	2,200 b	1.49 a	33.2 b	---
120	13,500	0.92 b	471 b	128 ab	30.9	2,100 b	1.63 b	34.3 b	---
	NS				NS				
				1989					
0	20,100	0.74 a	410 a	120 a	32.1 a	1,500a	1.37 a	20.2 a	2,600 a
60	19,900	0.90 b	498 b	154 b	33.1 ab	2,300 b	1.44 a	33.1 b	3,000 b
90	20,700	0.92 b	498 b	157 b	33.4 ab	2,500 b	1.56 b	38.7 c	3,100 b
120	19,900	0.92 b	503 b	160 b	34 b	2,500 b	1.59 b	39.2 c	3,000 b
	NS								

* Means for each parameter within year followed by the same letter are not significantly different at the 0.05 level.
NS = not significant at the 0.05 level.

In general, yield, yield components, and grain N removal data were better in 1989 than in 1988. This observation might be due to the 20-day earlier planting date in the second year. This because of the known fact that planting date controls indirectly microclimate, and subsequently soil conditions which in turn affect plant growth and development.

From grain yield and grain N uptake data, one can conclude that:

1) The 90 kg N/fa would be sufficient for maximum yield of cv. Giza-2 planted on such a fertile soil.
2) The yield goal or production level affects both the N fertilizer requirement and crop N removal.

Effect of P_2O_5 rates on vegetative growth parameters

In 1988, there were no significant differences in any of the measured vegetative parameters with increasing P_2O_5 rate from zero to 40 kg/fa. Similar results were observed in the second year on the same parameters, except for ear height and leaf area (Table 16). Forty kg P_2O_5/fa significantly increased both leaf area and ear height than those of the control, this might be due to the vital role of P in cell division. Yet, there was no significant difference in both parameters as P_2O_5 rate increased from 20 to 40 kg/fa. Observations in both years of study indicate that the response of vegetative growth to P fertilizer rates was generally low. This result might be due to the nearly high level of 10 ppm available p in the soil.

Effect of P_2O_5 rates on yield, yield components, and grain N uptake

There were no significant responses observed on yield, yield components or grain N uptake as affected by P_2O_5 rates in 1988. In 1989, grain yield, grain N removal, and weight of kernel per ear were significantly higher at 40 kg rate as compared to the control (Table 17). The gradually increases in both grain yield and grain N uptake might be resulted from the slightly, nonsignificant increases in yield components as influenced by increasing P_2O_5 rates.

The increases in number and weight of kernels per ear, and grain yield with the application of P fertilizer might be due to the important role of P on corn growth and development. Streeter and Barta (1988) and Gardner *et al.* (1990) stated that P is an essential component of the energy transfer compounds (ADP and ATP), the genetic information system (DNA and RNA), cell membranes (phospholipids), and phosphoproteins. These results of the effects of fertilizer P on growth characteristics, yield, and its components are in accordance with those previously discussed in the review of literature section in this text (Bakr and Raafat, 1958; Muhammad and Main, 1985).

Effect of K_2O rate on vegetative growth , yield, yield components and grain N uptake

Data recorded in both years of study on all measured parameters as affected by application of 40 kg K_2O/fa showed no significant differences as compared to the control (without K fertilizer), therefore those data are not presented here. This result might be due to the high level of soluble K (0.3 meq/100 g soil) in preplanting soil analysis. Similar results for grain yield

Table 16. Vegetative growth parameters of corn as influenced by P fertilizer rate in the 1989 growing season.

P_2O_5 (kg/fa)	Plant ht cm	Ear ht cm	Stem diam. mm	Active leaf no.	Leaf area cm^2	Days to mid-silk. no.	Barren plants %	Lodged plants %
0	246	102 a *	16	10	602 a	67.9	11.2	10.1
20	251	105 ab	16	9.7	614 ab	67.7	9.3	8.3
40	252	108 b	16	9.9	646 b	67.6	9.7	9
	NS		NS	NS		NS	NS	NS

* Means for each parameter followed by the same letter are not significantly different at the 0.05 level.
NS = not significant at the 0.05 level.

Table 17. Yield, yield components and grain quality of corn as influenced by P fertilizer rate in the 1989 growing season.

P_2O_5 (kg/fa)	Populat-ion/fa no.	Ear/ plant no.	Kernel/ ear no.	Wt ear kernels g	Wt/100 kernel g	Grain yield kg/fa	Grain N %	Grain N uptake kg/fa	Stover yield kg/fa
0	19,900	0.86	472	143 a *	32.6	2,100 a	1.50	31 a	2,800
20	20,200	0.88	475	145 a	32.8	2,200 ab	1.47	32.4 ab	3,000
40	20,400	0.87	485	155 b	34	2,300 b	1.50	35 b	3,000
	NS	NS	NS		NS		NS		NS

* Means for each parameter followed by the same letter are not significantly different at the 0.05 level.
NS = not significant at the 0.05 level.

were obtained by Hamissa *et al.* (1971), and Sabir *et al.* (1987), However; the findings of Kandil *et al.* (1984), and Chattaraj *et al.* (1985) almost disagree with the findings reported herein.

NPK interaction effects

Except for P x K effect on kernel number per ear in 1989, and N x P x K effect on grain N content in 1988, there were no significant effects observed in both years for other possible interactions on all other measured parameters. Increasing P_2O_5 rates within the same K_2O rate did not significantly affect the number of kernels per ear except for the second 20 kg P_2O_5 increment with 40 kg K_2O rate (Table 18). The differences between 20 and 40 kg P_2O_5 within 40 kg K_2O rate or between zero and 40 kg K_2O within 20 kg P_2O_5 seem to be random and are not true due to the treatment effects.

As for grain N percent, differences among N rates within same P_2O_5 or K_2O rates on grain N content are evident (Table 19). There is a trend of this content to increase with increasing N rates. In contrast, no differences within any N rate could almost be detected, regardless of the rates of P_2O_5 and K_2O. It is apparent that neither P nor K had any substantial effect on grain N content and this interaction is mainly resulted from the single effect of N rates.

Table 18. **The number of kernels/ear in the 1989 experiment as a function of P and K fertilizer rates.**

K_2O (kg/fa)	P_2O_5 (kg/fa) 0	20	40
	------------Kernels no./ear----------------		
0	463 ab *	493 a	476 ab
40	481 ab	457 b	494 a

* Means in both columns and rows followed by the same letter are not significantly different at the 0.05 level.

Table 19. **Grain N content in the 1988 experiment as a function of N, P and K fertilizer rates.**

P_2O_5 (kg/fa)	K_2O (kg/fa)	N rate (kg/fa) 0	60	90	120
		---------------Grain N uptake (kg/fa)-----------------			
0	0	22.0 d-f *	37.1 a	36.6 a	28.0 a-f
0	40	22.2 d-f	30.7 a-e	32.3 a-e	36.1 a
20	0	16.5 f	31.7 a-e	36.5 a	36.0 ab
20	40	23.5 c-f	24.1 c-f	32.1 a-e	33.0 a-d
40	0	21.0 ef	25.8 a-f	24.2 b-f	37.6 a
40	40	20.9 ef	32.1 a-e	37.5 a	35.2 a-c

* Means in both columns and rows followed by the same letter are not significantly different at the 0.05 level.

II. UNMANURED AND MANURED N RESPONSE EXPERIMENTS

Yield responses

There was an evident and positive grain yield response of unmanured corn to N fertilizer rates, but not with manured corn (Table 20, Fig. 8 a). A maximum corn grain yield of 9.44 Mg/ha (66% over the control) was obtained by the application of 200 kg N/ha to unmanured corn. This maximum yield, did not differ significantly from other yields resulted from the other N rates ranging from 120 to 280 kg/ha. However, in manured corn, the unfertilized plots gave a maximum yield of approximately 9.0 Mg/ha which equaled to that of 120 kg N rate of unmanured corn. This means that manuring corn plots could substitute efficiently the 120 kg N rate for grain yield production. The last observation might be due to the function of manure in supplying macro-, and micronutrients to soil, in addition to improving other chemical, physical, and biological soil conditions with manure application.

Stover yield of unmanured corn responded significantly to N rates (Table 20, Fig. 8 b). A maximum stover yield was obtained from the 120 kg N/ha treatment. There were no significant differences observed on stover yield by increasing N rate from 80 to 280 kg/ha. Stover yield of unmanured corn was not significantly affected by N fertilizer levels.

Total yield of unmanured corn was significantly higher with fertilized plots than with the control (Table 20). A maximum total dry yield (roughly 15 Mg/ha) resulted from both 120 and 280 kg N rates with no significant difference between the two rates. Similar to stover yield, total yield of manured corn was not significantly influenced by N rates.

Table 20. Grain, stover, and total yields of corn as affected by N fertilizer rates under unmanured and manured corn conditions.

Non-starter N rate	Grain yield♣				Stover yield		Total yield	
	unmanured		manured		unmanured	manured	unmanured	manured
kg/ha	Mg/ha	%	Mg/ha	%	Mg/ha	Mg/ha	Mg/ha	Mg/ha
0	5.67 d*	100	8.97 a	100	4.19 c	5.72	8.98 c	13.79
40	7.64 c	135	7.75 bc	86	5.96 b	5.44	12.42 b	11.99
80	8.37 bc	148	7.91 abc	88	6.50 ab	6.01	13.57 ab	12.69
120	8.98 ab	158	8.65 ab	96	7.43 a	6.02	15.02 a	13.34
160	9.36 a	165	7.81 abc	87	6.80 ab	5.14	14.72 a	11.74
200	9.44 a	166	8.52 ab	95	6.80 ab	5.59	14.78 a	12.79
240	9.18 ab	162	7.31 c	81	6.65 ab	5.37	14.40 a	11.55
280	9.08 ab	160	8.78 a	98	7.42 a	6.01	15.09 a	13.96
						NS		NS

♣ Grain yield was corrected to 15.5 % moisture. Stover yield and total yield were calculated on an oven-dry basis.
* Means in each column followed by the same letter are not significantly different at the 0.05 level.
NS= not significant at the 0.05 level.

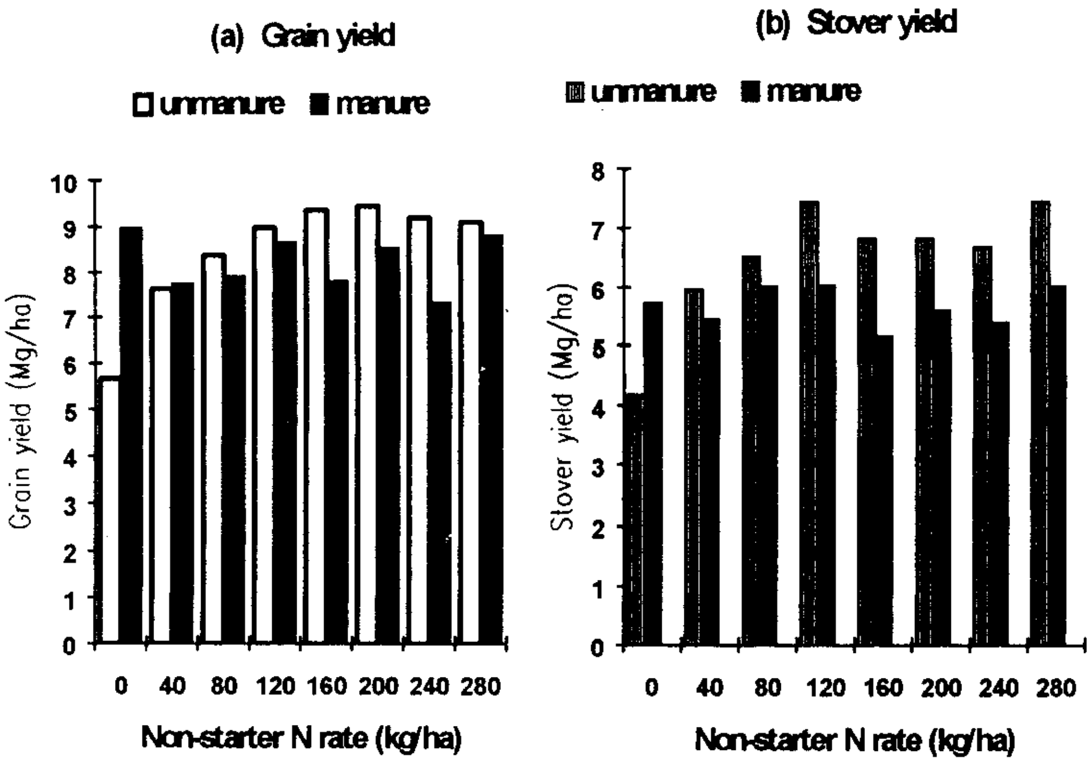


Fig. 8. (a, b) Grain, and stover yields of corn as affected by N fertilizer rates under unmanured and manured corn conditions.

These data suggest that manuring corn can efficiently replace chemical N fertilizer application. The amount of manure applied, kind, analysis, timing, and frequency should be given attention to gain the maximum profits and to minimize the harmful impact of nitrate on environments.

Roth *et al.* (1991) reported that soil fertility management is a key of corn production in Pennsylvania because it can influence both the profitability and the environmental risks associated with corn production. In addition, the environmental risks of corn production have increased where malmanagement of soil fertility levels have resulted in excessive N or P accumulations in the soil. These can contribute to nitrate leaching problems in ground water or phosphorous runoff into surface water.

The nonsignificant differences between the maximum and other grain yields of unmanured corn should be discussed from the viewpoint of production economics.

N uptake responses

All determined parameters of unmanured corn significantly responded to N fertilizer rates (Table 21). Maximum grain N uptake resulted from 200 kg N rate with no significant differences were observed between 120 and 280 kg N rates. Stover, and total N uptake of unmanured corn were increased gradually by increasing N rates up to the maximum rate for stover (280 kg N/ha) and only up to 160 kg N rate for the total. This result may help in planning for good N management especially with corn silage quality. Grain N percent differed slightly as a function of N rate with 1.34 % being the highest

Table 21. Grain, stover, and total N uptake and grain N, stover N, and stover NO3-N concentrations as affected by N fertilizer rates under unmanured (unman.) and manured (man.) corn conditions.

Non-starter N rate kg/ha	N uptake						Grain N conc.		Stover N conc.		Stover NO3-N conc.	
	Grain		Stover		Total♣							
	unman.	man.	unman.	man.	unman.	man.	unman.	man.	unman.	man.	unman.	man.
	Kg/ha						%				g/kg	
0	55 c*	115	27 d	54	86 d	178	1.15 d	1.41	.63 d	.94	.03 c	.69 c
40	80 b	95	45 c	59	131 c	161	1.24 c	1.44	.75 cd	1.08	.04 c	1.06 b
80	85 b	94	48 bc	62	140 bc	163	1.20 cd	1.41	.73 cd	1.02	.04 c	.93 bc
120	102 a	103	54 abc	65	164 ab	176	1.34 a	1.41	.77 bc	1.07	.13 bc	.67 c
160	105 a	93	63 ab	57	176 a	157	1.33 ab	1.40	.92 a	1.12	.24 b	.89 bc
200	106 a	100	56 abc	58	171 a	165	1.33 ab	1.38	.88 ab	1.03	.19 bc	.85 bc
240	97 a	90	64 ab	60	169 a	157	1.25 c	1.45	.96 a	1.13	.42 a	1.45 a
280	97 a	115	70 a	67	175 a	191	1.26 bc	1.55	.94 a	1.10	.49 a	1.44 a
		NS		NS		NS		NS		NS		

♣ Total N uptake was calculated by multiplying the grain plus stover N contents by 1.05.
* Means in each column followed by the same letter are not significantly different at the 0.05 level.
NS= not significant at the 0.05 level.

value recorded at 120 kg N rate. Stover N concentration was almost increased gradually with increasing N rates. The highest value of 0.96 % was obtained from the 240 kg rate. No significant differences could be detected on this character between the rates of 160 and 280 kg N/ha. Almost, stover NO_3-N level was steadily increased by increasing N rates up to the maximum used N rate.

As for manured corn, except of stover NO_3-N, there was no significant effect observed on all other measured parameters of manured corn as affected by N rates (Table 21). However, most values pertaining to these characters seem to be higher at the higher N rates. Nitrogen rates significantly affected the level of stover nitrate-N. The highest values were observed at both 240 and 280 kg rates with no significant difference between them.

The nitrate-N results are in agreement with those reported by Natl. Res. Council (1978). They mentioned that N fertilization rate is an important factor affecting NO_3-N levels in plants. Also, they have shown a direct relationship between the amount of applied N and NO_3-N content of plants. In addition nitrate concentrations in plants are usually excessive when the rate of applied N rate is higher than that required to give maximum dry matter yield. High NO_3-N levels are normally associated with high total N contents in plants; however, there is no precise relationship between the concentrations of the two N components in plants. Aldrich *et al.* (1986) reported that the N in manure or legumes raises the nitrate content of corn stalks in the same way as N added in the form of chemical fertilizer. The most widely used figure for a deadly dosage is 0.93 % NO_3 in the total feed that is eaten. Silage with 0.3

to 0.6 % NO_3 should be fed with caution and that 625 mg NO_3/kg fed in a 24-h period is often fatal to ruminants.

Conclusion

Unmanured corn responded significantly to N fertilizer rates. This was evident with all measured parameters. The application of 200 kg N/ha to unmanured corn resulted in a maximum corn grain yield of 9.44 Mg/ha (66 % over the control). Except for grain yield and stover NO_3-N level, all other measured parameters did not respond to chemical N fertilizer applied to manured corn. Grain yield of manured corn was negatively affected by applied N rates. Manured corn without N addition produced as much grains as 120 kg N applied to unmanured corn. The quality of unmanured corn was improved by application of inorganic N. Almost, stover NO_3-N concentration of either unmanured or manured corn was gradually increased with increasing N rates. The highest values resulted from the highest N rates, however were below the fatal dosage to ruminants. These results suggest that manuring corn can efficiently replace inorganic N fertilizer application. The amount of manure or inorganic N applied to soil should be at optimum level to gain the maximum profits and to minimize the harmful effect of nitrate on environments.

III. Economic analysis: Comparisons of grain yield response to N rates at Moshtohor (Egypt) and in Central Pennsylvania (USA).

Effects of nitrogen fertilizer rate on some parameters determined from the quadratic linear plateau yield response functions are shown in table (22). The estimated values of economic, plateau, and maximum yields were generally higher in 1989 than in 1988. This result may be due to better environments, associated with earlier planting date, concomitant with corn plants in 1989 growing season. However, these yield values were much lesser than those calculated from N response experiment done in Central Pennsylvania in 1992. Economic optimum yield of 1992 experiment was about 69 % higher than that of the average of 1988 and 1989 experiments. The advantage in corn productivity observed in the experiment done in Pennsylvania probably was due to the used high yielding variety, longer day-period, early planting date (first wk. of May), soil fertility, or the interaction among them. The great difference between maximum and minimum air temperatures in Central Pennsylvania vs. Moshtohor (Tables 1,4 in Materials section) which in turn increases net assimilation rate of corn plants might be the other reason for this advantage. Economic optimum N fertilizer rates were 77, 91, and 60 kg N/fa for 1988, 1989, and 1992, respectively, and all were lower than that needed to reach the yield plateau. The differences between the economic optimum N rates and the maximum used N rates were 43, 29, and 58 kg/fa in 1988, 1989, and 1992, respectively. These excesses in the used N fertilizer (than the amount required for the economic optimum yield) are considered wasteful in fertilizer costs and could be involved in polluting water resources. Also, this economic analysis showed that each one kg N applied at economic optimum level contributed an average of 27.5 kg for 1988 and 1989, and 65 kg for 1992 of the total grain yield production. The 1992 results were in agreement with those observed in Central Pennsylvania (USA) by Fox and Piekielek, (1987).

It should be noticed that these presented data are from two locations (Moshtohor for two yr. and Pennsylvania for one yr.), so economic optimum

N rate could be recommended only for similar conditions. Other experiments with recommendations are needed for other locations, soil types, and corn cultivars over the countrywide.

Table 22. Maximum, plateau, and economic grain yields and plateau, and economic N rate as a function of N fertilizer rates applied in the 1988, 1989, and 1992.

Site-Year	N rate: Plateau Initiation	N rate: Econ.* Optim.	Yield: Max.	Yield: Plat.	Yield: Econ. Optim.	Grain yield per kg N applied at Econ. Optim.
	kg/fa					kg/kg
Moshtohor-1988	92	77	2220	2160	2142	28
Moshtohor-1989	103	91	2472	2477	2463	27
Penn State-1992	63	60	3965	3881	3887	65

* Calculated with a N fertilizer cost: grain price ratio of 1.087/0.464 (2.34), (both in L.E./kg).

SUMMARY

The objectives of this investigation were to:

1) evaluate the effects of GA3 and CCC as seed-soaking treatments at different rates and their interactions with N rate on growth, yield, and grain N uptake of cv. Giza-2 corn.
2) compare the effects of ethephon vs. Primo on vegetative growth, crop quality, and distribution of total yield among organs of corn plant shoot at harvest.
3) determine optimum time and rate of application of ethephon and Primo to minimize stalk lodging and to maximize yields of hybrid corn.
4) study the agronomic and economic responses of corn to different levels of N, P, and K as a balanced fertilizing management.
5) evaluate the yield and economic responses of hybrid corn to eight N rates under unmanured and manured corn conditions.

To accomplish **the first objective**, a 2-year (1988, 1989) field study was conducted at the Agric. Res. Center. of Faculty of Agric., Moshtohor, Zagazig University (Benha Branch). The soil of the experimental field was clay textured with a pH of 7.97, had an organic matter of 2.3 %, and a total N of 0.14 %. The experiment was laid out in a strip plot design with four replications. The treatments were a factorial combination of five PGR treatments and three N rates for a total of 15 treatments. Treatments of PGRs were applied as seed-soaking solutions which were in 1988 and 1989 as follows:

1988	1989
1) Check (no-PGR added)	1) Check (no-PGR added)
2) GA3 at 150 ppm	2) GA3 at 75 ppm