DETAILS

Project number		M112/10
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Project manager		E Hugo
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Interactive effect between seed dressings on maize cultivars and the application of pre-emergence herbicides registered on maize

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Final abstract

Most maize cultivars are delivered to producers coated with an insecticide or fungicide or both as a seed dressing. Furthermore, the use of registered pre-emergence herbicides for the effective control of grasses and early season broadleaved weeds are still practiced by most maize producers. It was, therefore, necessary to evaluate the interactive effect between seed dressings and the continuous use of pre-emergence herbicides on the germination and emergence of maize seedlings. The interaction effect was determined on treated and untreated maize seed of five Pannar and six Pioneer Hi-Bred cultivars. Seed from Pannar was treated with Celest®, Mollyflo and Copperfos and seed from Pioneer was treated with Poncho®. Herbicides containing the following active ingredients acetochlor 700 g ai (Wenner®), acetochlor 840 g ai (Guardian®) and s-metolachlor 915 g ai (Dual Gold®) were applied at the registered label rate (LR) and double the LR. Cultivars treated with the respective seed dressings of both Pannar and Pioneer Hi-Bred emerged faster and the total number of seedlings emerged was higher when compared to untreated seed. The interaction

between seed dressing and herbicides applied was significant for plant height and dry mass of Pannar cultivars. Maize seedlings were stunted (> 20 %) where double the label rate of all herbicides was applied. However stunting of untreated Pioneer Hi-Bred cultivars was only 17 % when double LR of Wenner® was applied. The same tendency for dry mass was observed for Pannar cultivars, but dry mass of Pioneer Hi-Bred cultivars was not significantly affected by seed dressing and herbicide application. Phytotoxicity tended to be more severe where Pannar seed was treated but the effect was only significant for PAN6P-110 (23 %). All Pioneer Hi-Bred cultivars tested however showed more phytotoxicity (25 - 36 %) where seed was not treated. The interaction between seed dressings and herbicide applications was cultivar related and was mostly significant for the first four weeks after emergence (WAE), but all seedlings outgrew stunting and visual phytotoxicty symptoms 10 WAE.

Introduction

It is essential that plant density be kept uniform throughout a field, as should be the age and stage of development of the crop (Zaborszky, 2004). Optimal seed storage conditions under which seed vigour and viability could be maintained are essential for effective crop production in the following season (Basra, 1995). Seed vigour and viability is primarily based on generic factors, therefore differences occur among species and varieties within a species. The conditions under which seed is produced can also affect its longevity. Temperature, rainfall, humidity, nutrition and diseases during seed production all affect seed viability, as does seed maturity when harvested (Copeland & Miller, 2001; Vogel, 2002; Zaborszky, 2004). Although some pre-sowing seed treatments may improve germination and field emergence under detrimental environmental conditions (Copeland & Miller, 2001; Vogel, 2002; Murungu. 2004; Zaborsky *et al.*, 2005), farm- applied seed dressings (Zaborszky, 2004), seed size (Wulff, 1986), seed age (Vinkovic, *et al.* 2007), unfavourable storage conditions (Volenic *et al.*, 2007) and environment X seed dressing herbicide interactions (Johnson, 1981; Khan *et al.*, 1981; Rehman *et al.*, 1998; Saayman, 2002; Zaborszky, 2004) often cause decreases in seed vigour, resulting in reduced plant stand.

Seed treatments are added to seed to enhance germination and emergence of seedlings during the critical first few weeks after planting. Maize seed is treated with either a fungicide (Captan® or Celest®) or insecticide (Cruiser®, Gaucho®, Poncho®,) or with both before planting to protect emerging seedlings from soil-borne fungal diseases and insect pests. Insecticidal seed dressings can also protect stored maize seed from infestations of pests such as grain borers, weevils and grain beetles. Most prominent seed companies such as Pannar, Monsanto and Pioneer Hi-Bred, deliver seed to producers with either an insecticide or fungicide, or both applied as seed dressings. Some seed companies also add nutritional products such as boron and molybdenum to their seed dressings to enhance seedling germination, vigour and emergence. Unregistered or self-mixed seed dressings added to seed on-farm are highly unreliable and is not recommended, but are still being practiced by some maize producers. Because of worldwide economic pressure information on variables affecting the quality of seed and crop stand is of utmost importance to producers and seed companies. Information of this kind is especially important in Africa where a variety of crops/cultivars are mostly grown under unfavourable environmental conditions. Pre-emergence soil applied herbicides are recommended mostly for effective control of grass and broad leaf weeds early in the season. Due to these practices maize producers requested via Grain SA that the interaction between different seed dressings and pre-

emergence herbicides be investigated to determine the effects on germination and emergence.

Materials and Methods

Greenhouse trials were conducted on maize at Potchefstroom using five cultivars from Pannar and six cultivars from Pioneer. Two batches of seed were tested, one with the relevant seed dressing applied by the seed company (treated) and one batch that was not treated (untreated) (Table 1). Three soil applied herbicides, registered for pre-emergence use on maize was applied at the label rate (LR = 1X) and double the label rate (LR = 2X) (Table 2). Eight seeds per 4 L pot were planted in a clay soil (35 %) and thinned out to four plants seven days after planting (DAP) (240 pots for Pannar and 288 pots for Pioneer Hi-bred cultivars). The experimental design was a complete randomised block design with four replicates per treatment. Pots were lined with plastic bags to prevent contamination from previously used herbicides. Seeds were planted at a depth of 4 cm and herbicides were applied the following day. Field capacity was determined before initiation of the trial, by means of pot-weighing methods and pots were watered daily accordingly. Holes at the bottom of each pot allowed free drainage. Chemicult fertilizer was applied to each pot (±100 ml) after emergence for all the seedlings. Each pot received 250 ml water after herbicide application to ensure activation of the herbicides. Optimal growing conditions were maintained in the glasshouse at 15° / 30°C, (night / day) for the duration of the trial under natural daylight conditions

The mean time to emergence (MGT), total number of emerged seedlings and visual symptoms of phytotoxicity were recorded throughout the observation period. Plant height was measured weekly and dry mass was determined at 54 DAP when trials were terminated and expressed as a percentage of the control treatments. The above-ground plant parts were cut off and dried at 60°C for 48 hours. Visual phytotoxicity was observed as skew growth of coleoptile, curling of leaves, whiplashing of leaves, chlorosis, stunting and malformation of plant parts and was recorded by comparing plants in seed and herbicide treatments with those at the untreated control. Visual phytotoxicity was expressed as a percentage of the untreated control treatments (Bleiholder, 1997).

Data variables were subjected to a factorial analysis of variance with cultivars as factor 1, seed dressing as factor 2, and herbicide rates as factor 3 using Genstat® for Windows Release 14.1 (Payne et al, 2011). Means were compared at P=0.05 using Fisher's Unprotected LSD.

Table 1 Maize cultivars of Pannar and Pioneer Hi-bred with relevant seed dressings applied.

Cultivars	Seed dressing	Active ingredient
PAN5Q-433BT	Celest® (fungicide)	Fludioxonil/ mefonoxam
PAN6236BT	Copperfos	Copper phosphate
PAN6Q-445B	Mollyflo	Sodium molybdate
PAN3Q-740BR		
PAN6P-110		
PHI30B97BR	Poncho® (insecticide)	clothianidin
PHI30D09BR		
PHI30Y79B		
PHI31G54BR		
PHI31R58B		
PHI32D95BR		

Table 2 Herbicide and dosage rates used in glasshouse trials.

Active ingredient	Product name	Dosage rate ($l.ha^{-1}$)
acetochlor 700 g ai	Wenner® 700 SE	1.7
		3.4
acetochlor 840 g ai	Guardian® 840 EC	1.0
		2.0
s-metolachlor 915 g ai	Dual Gold® 915 EC	0.65
		1.3

Results

Pannar cultivars

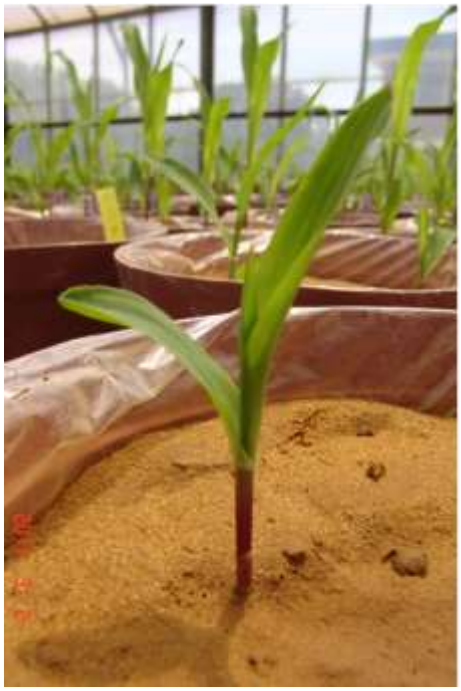
Mean time to emergence (MTE) and total number of seedlings emergence for Pannar cultivars were significantly influenced by seed dressing and cultivars. A significant interaction between different cultivars and seed dressings ($F = 3.23$, $P = 0.013$) was recorded for MTE and total seedlings emerged. Herbicide treatments only influenced total number of seedlings significantly ($F = 6.31$, $P < 0.001$). Seed dressing had the greatest effect on MTE ($F = 405$, $P < 0.001$) and total seedlings emerged ($F = 755$, $P < 0.001$). Pannar cultivars with seed treatment (treated) emerged within four days after planting while cultivars with no seed treatment (untreated) took an average of six days to emerge (Fig. 1). Total seedlings emerged was higher for treated cultivars and an average of six plants emerged per cultivar, while only four plants per untreated cultivar emerged (Fig. 1).

Plant height was significantly influenced by both seed dressing and herbicide treatments. Herbicide treatments had the greatest effect on plant height for the first three WAE, after which seed treatment had the greatest effect. Wenner® and Dual Gold® applied at double the LR dosage significantly stunted all cultivars for the first eight weeks after emergence but then the plants outgrew the stunting by 10 WAE (Fig. 2). The interaction between seed dressing and herbicide treatments was significant for both mean plant height and dry mass (Table 3). Pannar cultivars with seed treatment showed significant more stunting compared to cultivars with no seed treatment. This was especially observed where Guardian was applied at LR and double the LR dosage on treated seed (> 12 %). Plant height was reduced more than 20 % where Wenner® and Dual Gold® was applied at double the dosage rate on treated seed. However where herbicides were applied at registered LR stunting was less than 10 % on Pannar cultivars. The same tendency was observed for dry mass and the lowest mass (> 20 %) was recorded where double the LR of herbicides were applied on treated seed (Table 3).

Phytotoxicity on Pannar cultivars was mostly observed as a tight folded coleoptile, usually dark green in colour and twisting or curling of the whirl. These symptoms were observed only for up to 2 WAE (see photos). Although the seed treatment X herbicide application interaction was significant ($F = 15.43$, $P < 0.001$), herbicide application ($F = 45.33$, $P < 0.001$) had the greatest influence on phytotoxicity for the relevant Pannar cultivars. PAN5Q-

433BT showed the most visual symptoms where Wenner® and Dual Gold® were applied at double the LR on treated seed. Untreated seed of most Pannar cultivars tested tended to show more phytotoxicty, but the opposite was recorded for PAN6P-110 (Table 4). Cultivars, both treated and untreated seed, outgrew these phytotoxicity symptoms at 4 WAE and no visual symptoms, other than stunting, was observed at 10 WAE.

Photos: Visual phytotoxicity observed on Pannar cultivars and control plants



Pioneer Hi-Bred cultivars

Seed treatment ($F = 70.86$, $P < 0.001$) had the greatest effect on time of emergence followed by herbicide treatments ($F = 19.74$, $P < 0.001$) on Pioneer cultivars. Significant interactions between seed treatment and cultivars ($F = 8.65$, $P < 0.001$) and seed treatment and herbicide applications ($F = 8.53$, $P < 0.001$) were recorded (Fig. 3 and 4). Pioneer cultivars treated with Poncho emerged within five days after planting and faster when compared to seed without treatment (Fig. 3). PHI30Y79B treated with Poncho® emerged first of all the cultivars tested. Seed (Treated and Untreated) in the herbicide control treatments emerged also five days after planting. The untreated seed emerged significant later where Wenner® were applied at LR and double the LR compared to treated seed and the other herbicide treatments (app. 6 days) (Fig. 4).

Significant stunting was only observed for the first 4 to 6 WAE where Wenner® was applied at double the LR, but at 10 WAE all seedlings in all the herbicide treatments compared good with control plants and outgrew the stunting effect (Fig. 5). The interaction between seed treatment and herbicide application was only significant for average plant height but not for dry mass (Table 5). Plant height of maize seedlings was significant lower where seed was untreated and Wenner® applied at double the LR showed the most stunting (12 %).

Visual phytotoxicity was observed as tight folding of the coleoptile (dark green in colour), twisting of the whirl and stunting, but was only observed for 2 WAE. Although a significant interaction between cultivars, seed treatment and herbicide application ($F = 2.39$, $P < 0.001$) was recorded, the greatest effect on phytotoxicity was due to seed treatment ($F = 172$, $P < 0.001$) and herbicide applications ($F = 171$, $P < 0.001$). Untreated seed showed more phytotoxicity for all cultivars (25 - 35 %) tested and only PHI30Y79B showed less than 20 % phytotoxicity. Phytotoxicity for cultivars treated with Poncho® varied between 7 and 16 % (Table 6). Application of Wenner® at both LR and double the LR resulted in visual phytotoxicity greater than 20 % which is commercially unacceptable at 42 % and 58 %, respectively. All Pioneer cultivars tested outgrew these symptoms 4 WAE and growth was comparable to control treatments at 10 WAE when no visual symptoms could be observed.

Photos: Visual phytotoxicity observed for Pioneer cultivars



Discussion

Seed germination can be defined as the ability to develop into normal seedlings under optimal environmental conditions (TeKrony *et al*., 1999; ISTA 2007). High seed vigour, however, is characterised by the seed's ability to germinate and for the embryo to develop under stressful and detrimental conditions, which include compacted soil, pathogens, salinity and extreme cold or hot conditions (Hampton & TeKrony, 1999). The addition of any seed dressing in the form of an insecticide or fungicide and even nutritional additives are therefore done by companies to enhance germination and protect seedlings at the early growth stages of maize plants. When herbicides are also applied to soil the question arises if these methods can cause chemical-related stress to seed that has to germinate in already stressful conditions. Plant densities are one of the most critical factors that can have a significant effect on yield as modern cultivar development depends to a great extent on higher population densities and ear prolification. Although this study has tested only a few cultivars from two maize seed companies, the interaction between seed dressings and herbicide applications could be established. Seedling emergence was positively affected by the various seed treatments of the relevant cultivars tested and total number of seedlings emerged were higher where seed was treated. Furthermore, seed from both companies emerged faster when seed was treated compared to seed that received no dressing. The % visual phytotoxicity was higher for Pannar cultivars, but only one cultivar (PAN6P-110) showed significantly more symptoms where seed was treated, while the rest of the cultivars showed no significant interaction between treated and untreated seed. Pannar cultivars showed visual phytotoxicity of between 10 to 43 % where herbicides were applied and were more sensitive to double dosage rates. Pioneer cultivars were less sensitive to double dosage rates and only Wenner®, at both dosage rates showed phytotoxicity that was commercially unacceptable. Stunting of seedlings was observed for both Pannar and Pioneer cultivars but only for the first few weeks after emergence. Seedling height showed contradictory results; Pannar seedling height was significantly lower where seed was treated, but Pioneer seedling height was lower in untreated seed. It is, however, very important to note that all cultivars from both companies outgrew these stunting effects, as well as visual phytotoxicity symptoms 10 weeks after emergence. Dry mass was adversely affected by seed treatment for treated Pannar cultivars, but not for Pioneer cultivars. The interaction between seed dressings and herbicide applications is cultivar related, and was mostly significant on plant height and phytotoxicity only during the first weeks after emergence.

Seed treatment with Celest®, Mollyflo and Copperfos gave severe phytotoxic symptoms on maize seedlings of Pannar cultivars, as well as reduced dry mass. In a previous study done

on seed dressing and storage conditions, it was also reported that Celest® in combination of Cruiser significantly reduced germination of smaller maize seed. Pioneer Hi-Bred cultivars treated with Poncho® alone showed less phytotoxic symptoms and plant height and dry mass was not adversely affected by the seed dressing and herbicide interaction. Herbicide damage to crops is rarely only due to the herbicide(s) alone and detrimental environmental conditions (cold and wet weather during application) or inaccurate dosage rates are important factors playing a role in the severity of the damage. Registered seed dressings can only be done by seed companies and on-farm seed treatments is not recommended. The findings of this study proved that Poncho® seed dressing is safe to use on Pioneer Hi-Bred cultivars tested in this study.

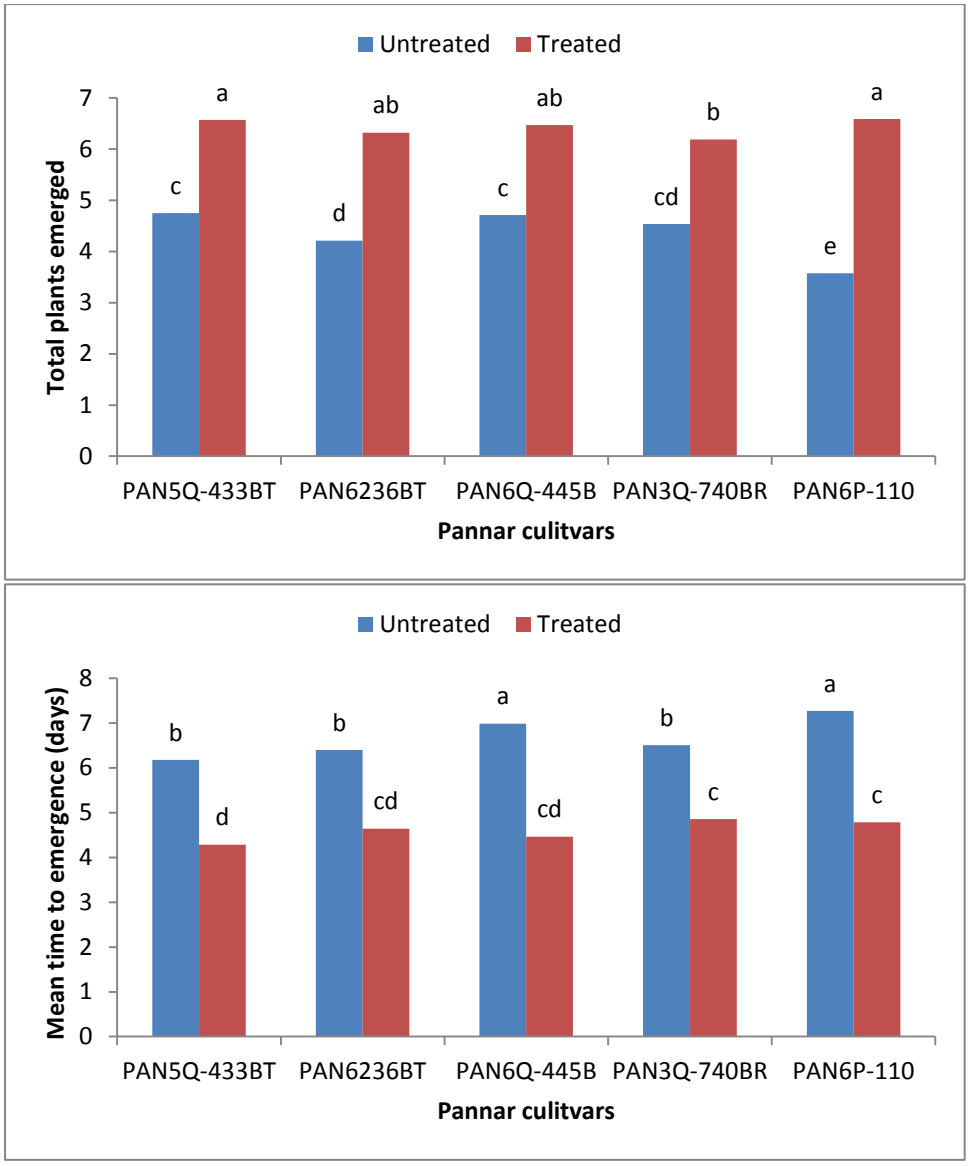


Fig 1 Mean time of emergence and total seedlings emerged of five Pannar culitvars as influenced by seed treament (Celest®, Mollyflo and Copperfos) and seed without any treatments. (Bars with different letters indicate significance at P = 0.05)

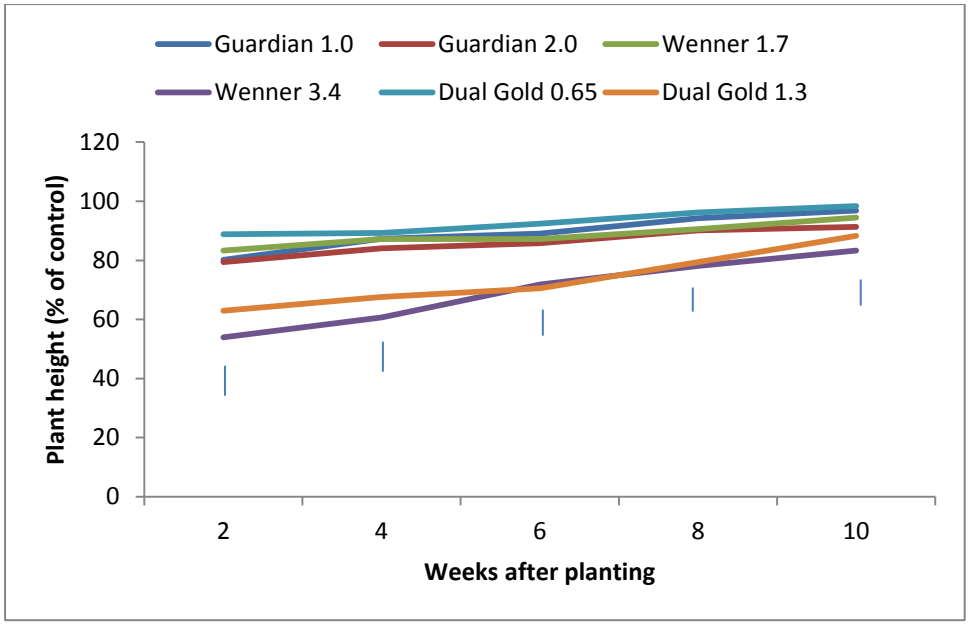


Fig 2 Effect of herbicide treatments on plant height of maize seedlings (Pannar culitvars) measured at weekly intervals. (Vertical bars indicate $LSD_{(0.05)}$)

Table 3 The effect on mean plant height and dry mass, expressed as a % of the control treatments, of herbicide and seed treatments on five Pannar culitvars.

Seed dressing	Herbicides							
	Control	Guardian 1.0	Guardian 2.0	Wenner 1.7	Wenner 3.4	Dual Gold 0.65	Dual Gold 1.3	Mean*
	Plant height (% of control)							
Untreated	100	98.08	98.05	91.01	78.93	94.05	81.16	91.61b
Treated	100	85.01	76.9	89.12	67.77	94.72	71.98	83.64a
Mean*	100a	91.54bc	87.47d	90.06cd	73.35e	94.38b	76.57e	
$LSD_{(Interaction)}$ = 5.38								
	Dry mass (% of control)							
Untreated	100	106.10	88.60	92.30	73.30	98.70	86.00	92.20a
Treated	100	75.00	62.00	87.70	63.20	95.40	73.70	79.60b
Mean*	100a	90.54ab	75.27cd	90.01b	68.28d	97.07ab	79.84c	
$LSD_{(Interaction)}$ = 13.72								

* Different letters in rows and columns indicate significance at P=0.05 (Fisher's Unprotected LSD values)

Table 4 Visual percentages of phytotoxicity as influenced by three herbicides and seed treatments on five Pannar cultivars

Pannar Cultivar	Seed dressing**	Herbicides (g ai ha^{-1})							
		Control	Guardian 1.0	Guardian 2.0	Wenner 1.7	Wenner 3.4	Dual Gold 0.65	Dual Gold 1.3	Mean*
5Q-433BT	UT	0	58.34	56.25	45.83	45.84	14.58	37.50	36.91a
	T	0	30.00	22.41	36.81	60.70	6.25	81.30	33.92a
6236BT	UT	0	33.33	47.92	14.58	22.92	35.42	52.08	29.46ab
	T	0	30.42	33.20	1.67	50.56	2.08	45.70	23.38bc
6Q-445B	UT	0	20.83	41.66	16.66	8.33	16.67	22.91	18.15c
	T	0	16.48	20.56	6.94	37.97	0.00	41.25	17.60c
3Q-740BR	UT	0	33.34	45.84	8.33	14.58	20.83	41.67	23.51bc
	T	0	20.00	26.67	0.00	50.00	0.00	45.70	20.34c
6P-110	UT	0	0.00	12.50	12.50	6.25	0.00	4.17	5.06d
	T	0	15.00	38.75	0.00	51.67	0.00	55.14	22.94bc
Mean*		0e	25.77c	34.57b	14.33d	34.88b	9.58d	42.74a	

LSD (Seed treatment x cultivar x herbicide) = 20.40

* Different letters in rows and columns indicate significance at P = 0.05 (Fischer's Unprotected LSD values)

** UT = untreated seed, T = seed treated with Celest®, Copperfos and Mollyflow

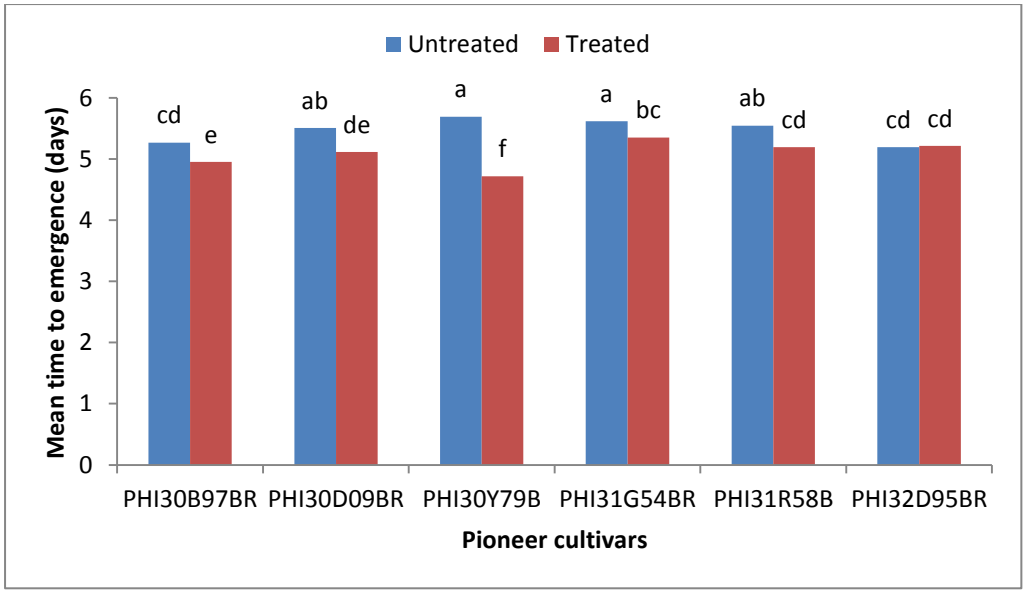


Fig. 3 Mean time to emergence of six Pioneer Hi-Bred maize cultivars as influenced by seed treatment with Poncho® and seed without any treatment. (Bars with different letters indicate significance at P = 0.05)

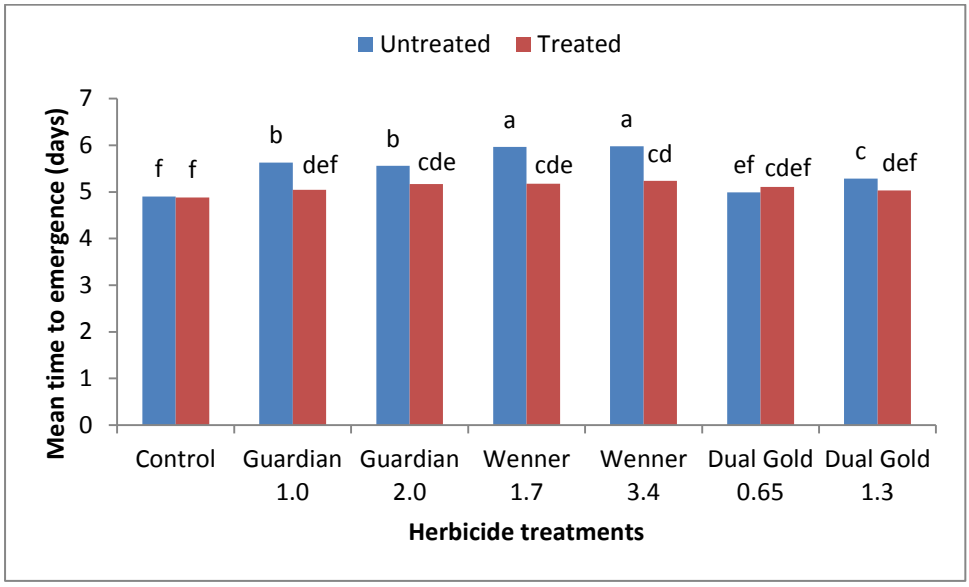


Fig. 4 Effect of herbicide treatments on the mean time to emergence of Pioneer maize culitvars treated with Poncho® (Treated) and seed without any treatment (Untreated). (Bars with different letters indicate significance at P=0.05)

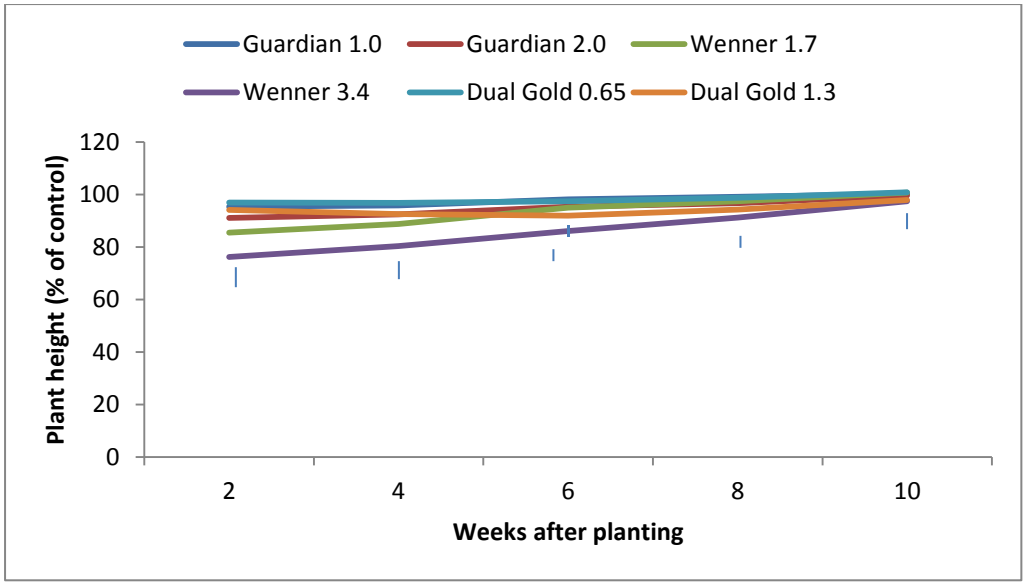


Fig. 5 Effect of three herbicides at standard label rates and double the label rates on mean plant height of maize seedlings (Pioneer Hi-Bred cultivars) measured at weekly intervals. (Vertical bars indicate $LSD_{(0.05)}$)

Table 5 Effect of seed and herbicide treatments on plant height of six Pioneer Hi-Bred cultivars.

Seed dressing**	Herbicides (g ai ha-1)							
	Control	Guardian 1.0	Guardian 2.0	Wenner 1.7	Wenner 3.4	Dual Gold 0.65	Dual Gold 1.3	Mean*
Untreated	100	95.86	94.26	91.99	83.37	95.74	90.09	93.04b
Treated	100	101.28	98.12	98.69	94.08	102.03	99.73	99.13a
Mean*	100a	98.57a	96.19a	95.34b	88.73c	98.88a	94.91b	
$LSD_{(interaction)}$ = 2.67								

* Different letters in rows and columns indicate significance at P = 0.05 (Fisher's Unprotected LSD values)

** Seed treated with Poncho®

Table 6 Effect of seed and herbicide treatments on the visual phytotoxicity of six Pioneer Hi-Bred mazie cultivars.

Pioneer Hi-Bred Cultivar	Seed dressing**	Herbicides (g ai ha^{-1})							
		Control	Guardian 1.0	Guardian 2.0	Wenner 1.7	Wenner 3.4	Dual Gold 0.65	Dual Gold 1.3	Mean*
30B97BR	UT	0	26.25	42.81	50	77.81	17.5	10.94	32.19fg
	T	0	0	5	43.12	66.25	1.25	0	16.52cd
30D09BR	UT	0	40.62	54.06	48.75	75	5	6.25	32.81fg
	T	0	0	0	25	60.94	0	1.25	12.46abcd
30Y79B	UT	0	2.5	26.25	32.5	57.5	0	1.25	17.14d
	T	0	0	0	20	43.75	2.5	0	9.46ab
31G54BR	UT	0	17.5	38.12	45	59.06	8.75	12.5	25.85e
	T	0	0	7.19	26.25	39.38	2.08	1.25	10.88abc
31R58B	UT	0	37.5	35	87.5	72.5	11.25	7.5	35.89g
	T	0	3.75	11.25	31.88	55	0	0	14.55bcd
32D95BR	UT	0	27.5	14.06	64.69	75.31	0	6.25	26.83ef
	T	0	0	5	27.29	15	3.12	0	7.2a
Mean*		0a	12.97b	19.9c	41.83d	58.12e	3.93a	4.29a	
LSD (Seed treatment x cultivar x herbicide) = 16.15									

* Different letters in rows and columns indicate significance at P = 0.05 (Fischer's Unprotected LSD values)

** UT=untreated seed, T= seed treated with Poncho®

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